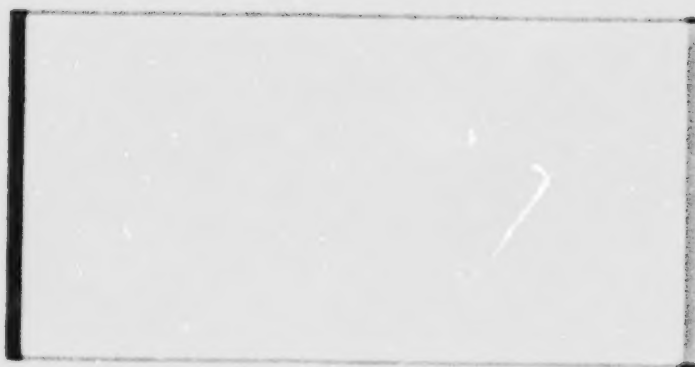




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MIRAMICHI ROCK CORE TESTS

Report No 85-223-K

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ABSTRACT

A series of granodiorite, diorite and granite specimens were selected from the rock core recovered during the recent in situ stress measurement program in the epicentral area of the 1982 Miramichi, New Brunswick earthquake and subjected to various laboratory tests. The results from the various tests provide basic information on the geomechanical properties of the three distinct rock types tested.

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MIRAMICHI ROCK CORE TESTS

1.0 PURPOSE

The purpose of this series of laboratory tests was to supplement the in situ stress information that was obtained in the epicentral area of the 1982 earthquake sequence in the Miramichi Region of New Brunswick during 1984. The results of this stress measurement study are detailed in McKay et al, 1985. These laboratory tests have provided general information on the geomechanical characteristics of the three major rock types encountered in the stress measurement study which can be used in future analysis of the seismicity in the Miramichi area.

2.0 SITE AND SAMPLE LOCATION

The site of the stress measurement project is shown in Figure 1. The locations of the boreholes are shown in Figure 2. The locations of the various test samples are shown in Figures 3 to 8.

2.1 General Sample Selection

The samples were chosen from various depths in all 6 boreholes in order to determine:

- 1) the variance in rock properties between the distinct rock types,
- 2) the variance in rock properties within one rock type,
- 3) the variance in rock properties with depth.

3.0 LABORATORY TESTING

Prior to the start of the laboratory testing programme, consideration was given to what tests would provide the most useful information with respect to the data needs of future studies on the Miramichi site. The final programme consisted of:

- 1) unconfined compressive strength
- 2) Young's modulus of elasticity (static)
- 3) Poisson's ratio (static)
- 4) density
- 5) porosity
- 6) absorption
- 7) mineralogy
- 8) compressional wave velocity
- 9) shear wave velocity
- 10) Young's modulus of elasticity (dynamic)
- 11) shear modulus (dynamic)
- 12) bulk modulus (dynamic)
- 13) Poisson's ratio (dynamic)
- 14) triaxial compressive strength
- 15) angle of internal friction
- 16) apparent cohesion
- 17) triaxial extension behaviour
- 18) direct tensile strength
- 19) deformation modulus under tensile loading
- 20) indirect tensile strength (Brazilian method)

The testing programme as originally planned (Table 1) divided the above series of tests into groups with a certain number of samples to be assigned to each group. This initial programme was based on testing one type of rock only. During the field testing it was apparent that there were three principal rock types at the site which were: 1) granodiorite, 2) diorite, 3) granite.

These rock types were determined by personnel from the New Brunswick Department of Natural Resources. The existence of three distinct rock types necessitated dividing the total number of tests applied to each rock type in order to stay within budget and time schedules.

The total number of tests that were applied to each rock type are outlined in Table 2.

3.1 Sample Selection

The different test specimens were chosen as close as possible to the location of the stress measurements made during the in situ stress study of the site (McKay et al, 1985). The test specimens were taken as close as possible to the stress tests and to each other in order to minimize variations that could be caused by weathering, or changes in mineral composition or rock fabric. Some test specimens were taken from the very near surface in order to determine the extent of strength change in the rock material due to surface weathering effects. Although there were three distinct rock types tested, it was apparent from the visual borehole logs that the granodiorite showed the greatest variability in grain distribution. It was anticipated that the

granodiorite structure would possibly indicate a larger variation in physical properties and so a total of 56 separate tests were performed on this rock type to ensure a realistic range of physical parameters were obtained for this rock type. The granite, which exhibited elastic anisotropy during field tests, had 47 separate tests performed on it while the diorite which behaved isotropically during field tests and appeared to be the most physically homogeneous had 37 tests. The distribution and numbers of these tests are given in Table 2. The first four figures of the sample number given to each test specimen indicate the borehole from which it was taken. The boreholes are the test holes used in McKay et al, 1985. These are:

borehole 1	3708
borehole 2	3709
borehole 3	3710
borehole 4	3711
borehole 5	3712
borehole 6	3713

3.2 Testing and Analytical Procedures

The guidelines that were used on this project for rock materials testing and the reporting of the test results as laid out by the American Society for Testing Materials (ASTM) and the International Society of Rock Mechanics (ISRM). A brief description of each test and its analytical method is given below.

3.2.1 Group I

A total of 34 specimens (13 granodiorite, 9 diorite, 12 granite) were tested for their unconfined compressive strength in accordance with ASTM procedures D2938-71a/5/, D3148-72/6/and the ISRM procedure/11/. The specimens were subjected to three load-unload cycles of up to 70% of ultimate before being loaded to failure. The Young's modulus of elasticity and Poisson's ratio were determined as average values for the last two load cycles. The Young's modulus (E) is an average value calculated from the straight line portion of the stress-strain curve where:

$$E = \frac{\sigma}{\epsilon_a}$$

E = Young's modulus of elasticity (MPa)
 σ = the applied compressive stress (MPa)
 ϵ_a = the axial strain of the sample measured during the test

The value of Poisson's ratio is defined by $\nu = \frac{\epsilon_r}{\epsilon_a}$

where: ν = Poisson's ratio

ϵ_r = the radial strain of the sample measured during the test

ϵ_a = the axial strain of the sample measured during the test

3.2.2 Group II

A total of 14 specimens (6 granodiorite, 4 diorite, 4 granite) were subjected to testing for density, porosity and absorption in accordance to ISRM guidelines/12,13/. These parameters are defined as:

$$\text{density} = \frac{\text{grain weight}}{\text{bulk volume}} \quad (\text{kg/m}^3)$$

$$\text{porosity} = \frac{\text{pore volume}}{\text{bulk volume}} \quad (\%)$$

$$\text{absorption} = \frac{\text{*mass of water}}{\text{dry mass of sample}} \times 100\%$$

*The mass of water is determined after a 1 hour immersion of the dessicator dry specimen in water.

Three specimens, one of each rock type, were prepared as thin sections and examined under a petrographic microscope using polarized light to determine their mineralogy.

3.2.3 Group III

A total of 46 specimens (17 granodiorite, 13 diorite, 16 granite) were tested ultrasonically in order to determine the compressional wave velocity (V_p) and the shear wave velocity (V_s) of each specimen. The test method employed conforms to ASTM D 2845-69/4/ and ISRM guidelines/14/. All unconfined compression samples and triaxial test cores were tested ultrasonically prior to being subjected to their specific tests. The pulse velocities for each specimen were determined under no load and then under uniaxial loading conditions. The uniaxial load was applied with a hydraulic jack pressurized with a hand operated pump with velocity readings being taken at 1 MPa (gauge) pressure increments over a range of from 1 MPa to 11 MPa (1.39 MPa to 15.35 MPa axial stress on the core). The compressional and shear wave velocities were determined for each 1 MPa (gauge) pressure

increase step during both the loading and unloading phases of each test. In addition to the measurement of V_p and V_s , the dynamic elastic constants were calculated at gauge pressures of 1 MPa, 6 MPa and 11 MPa during the loading cycle.

The elastic constants that were determined are:
Young's modulus of elasticity (E)

$$E = \frac{[\rho V_s^2 (3V_p^2 - 4V_s^2)]}{(V_p^2 - V_s^2)} \quad (\text{Pa})$$

where ρ = density (kg/m)

V_s = shear wave velocity (m/sec)

V_p = compressional wave velocity (m/sec)

shear modulus or modulus of rigidity (G)

$$G = \rho V_s^2 \quad (\text{Pa})$$

Poisson's ratio (μ)

$$\mu = \frac{(V_p^2 - V_s^2)}{[2(V_p^2 - V_s^2)]}$$

bulk modulus (K)

$$K = \frac{\rho (3V_p^2 - 4V_s^2)}{3} \quad (\text{Pa})$$

3.2.4 Group IV

The triaxial test group was comprised of 12 specimens (4 granodiorite, 4 diorite, 4 granite). The specimens were strain gauged for strain measurements in the axial and circumferential directions (Figure 9). The specimens were tested in accordance with the guidelines laid down by the ASTM/1/ and ISRM/10/. All specimens were loaded axially to failure while being subjected to various confining pressures which is also known as multiple failure state test. Confining pressures of 5, 10, and 15 MPa were used in all but one test. Specimen 3708 TR11 was loaded to failure with a confining pressure of 20 MPa in addition to the other three pressures. The data obtained from this series of tests were used to calculate:

- 1) the rock strength at the different confining pressures,
- 2) the Young's modulus of elasticity,
- 3) Poisson's ratio,

- 4) the apparent cohesion of the rock material,
- 5) the angle of internal friction of the material.

The term apparent cohesion (c) is used in the sense of Coulomb's failure theory

where: $\tau = c + \sigma \tan \phi$

τ = shear stress along the failure plane in the test specimen

c = inherent shear strength (apparent cohesion)

σ = normal stress on the failure plane in the test specimen

ϕ = angle of internal friction

The triaxial compression tests that were performed on the rock cores consisted of three separate load-unload cycles. The first load cycle was run with a confining pressure of 5 MPa while the second and third load cycles were run with confining pressures of 10 and 15 MPa respectively. One sample, P3708TRI2, was subjected to a fourth load cycle that used a confining pressure of 20 MPa.

The deformations of the test specimens were measured in the axial and radial directions by resistance strain gauges that were epoxied to the cores. The deformations were plotted on an XY chart recorder. For the diorite and granodiorite cores, the radial and axial gauges were applied as pairs with the pairs being applied located on opposite sides of the cores (Figure 10). The granite cores had four pairs of gauges applied to them at 90° intervals (Figure 11). The reason that so many gauges were applied to the granites was that this rock type had behaved anisotropically in a previous study (McKay et al, 1985) and its behaviour under triaxial conditions was uncertain.

The tests were performed on a Satec Universal Testing Machine with a load capacity of 2750 kN. The pressure cell that was used to apply the confining pressures to the samples was a Terrametrics Triaxial Confinement Chamber that was built by the Slope Indicator Co (Sinco) of Seattle, Washington. Prior to the start of the triaxial compression tests, the lateral pressure was increased while only a small axial load of 28 kN was applied in order to observe the behaviour of the core specimens under extension conditions.

3.2.5 Group V

This test group was comprised of 8 direct tensile specimens (3 granodiorite, 2 diorite, 2 granite) and 15 Brazilian type indirect tensile tests (9 granodiorite, 2 diorite, 4 granite). The direct tensile specimens were prepared and testing in accordance with test standards ASTM D2936/2/ and ISRM/15/. The Brazilian tests were performed in accordance with ASTM D3967-81/3/ and ISRM/16/ standards.

Each direct tensile specimen had 3 axial and 3 radial strain gauges epoxied to it located at 120° as shown in Figure 12. The cores were cycled three times when possible before being taken to failure in order to determine the values of the tensile modulus and the tensile ratio where:

$$\text{tensile modulus} = \frac{\text{axial stress}}{\text{axial strain}} \quad (\text{MPa})$$

$$\text{tensile ratio} = \frac{\text{circumferential strain}}{\text{axial strain}}$$

The individual rock types were cycled to what was estimated to be load that would not cause specimen failure but still yield useful results. Two cores, 3710TDT and 3712TDT, were tested without gauges for the purposes of estimating the failure loads for the weakest rock type, the granite (3710TDT) and the strongest rock type, the diorite (3712TDT). The third rock type, the granodiorite was expected to have a strength somewhere in between the other two as it had shown in other types of testing. These direct tensile tests were performed on a 22 kip servo hydraulic MTS fatigue machine.

The tensile strengths from the Brazilian type tests were determined with the formula:

$$\sigma_T = \frac{2P}{\pi LD}$$

where σ_T = splitting tensile stress (Pa)

P = maximum applied load (N)

L = length of specimen (m)

D = diameter of specimen (m)

4.0 TEST RESULTS

The results of individual test groups are discussed below. The summary tables containing the average test results are given at the end of this section.

4.1 Group 1

The test results of the 34 unconfined compressive strength tests are summarized in Tables 3,4 and 5. An engineering classification for each rock type based on Deere and Miller (1966) is given in Figures 13,14 and 15. A summary plot of all tests is given in Figure 16. The test results for each rock type are outlined below. The stress-strain curves for each test are contained in Appendix 1.

4.1.1 Granodiorite

The unconfined compressive strengths of the granodiorite ranged from 106.18 to 205.58 MPa while Poisson's ratio varied from 0.20 to 0.27. The stress strain curves indicate that the material is linearly elastic and Young's modulus of elasticity varies from 65,485 MPa to 77,121 MPa. This rock type usually has a high strength rating, although as can be seen from Figure 12, one sample of the 13 tested is rated as having a medium strength and another sample is very close to the division between the high and medium strength classes. Except for the two samples noted above the granodiorite samples had a high modulus ratio (M.R.) where

$$M.R. = \frac{\text{Young's modulus } 50\% \text{ ultimate strength}}{\text{uniaxial compressive strength}}$$

and high MR is $MR > 500$

medium MR is $200 < MR < 500$

low MR is $MR < 200$

The two exceptions noted above both had high M.R. values.

4.1.2 Diorite

The compressive strengths of this group ranges from 192.71 to 236.58 MPa while the Young's modulus varies from 65,762 MPa to 101,429 MPa and the Poisson's ratio has value spread of from 0.20 to 0.39. Three of the samples tested (Figure 13) are rated as high strength while the remaining six are very high strength. All samples are rated as having a medium modulus ratio.

4.1.3 Granite

The unconfined compressive strengths of the granite range from

146.95 to 209.78 MPa while the Young's modulus varies from 38,412 to 69,465 MPa and Poisson's ratio varies from 0.18 to 0.29. All 12 granite samples are rated as high strength with a medium modulus ratio.

A characteristic that was common to the behaviour of all three rock types was that of strain hardening as the uniaxial load was increased. In most cases and for all rock types the strain hardening seemed to cease when an axial stress of 20 to 25 MPa was attained and the sample had undergone approximately 500 microstrains in axial strain. The granodiorite samples seemed to indicate about the same amount of hysteresis upon unloading. This hysteresis was on the order of 80 microstrains with the largest values being at approximately the point at which the strain hardening behaviour stopped on the load portion of load unload cycle. The permanent hysteresis is on the order of 40 to 50 microstrains. The diorites from borehole 3 seem to exhibit very little hysteresis (10 to 20 microstrains) compared to the diorite samples from boreholes 2 and 4 (40 to 50 microstrains). The granodiorite specimens from borehole 3 show a decrease in the measured hysteresis (10 to 50 microstrains) as opposed to granodiorite samples from boreholes 1 and 2 (40 to 50 microstrains).

The granite specimens from boreholes 4, 5 and 6 show a similar variation in behaviour. The samples from borehole 5 show a smaller amount of hysteresis (20 to 50 microstrains) than samples from boreholes 4 and 6 (60 to 100 microstrains). The end of the strain hardening portion of the loading curve appears to occur at lower stresses (15 to 20 MPa) and axial strains (250 to 500 microstrains) for the samples from borehole 5 than for the samples from boreholes 4 and 6 which undergo the same behaviour at stresses of 25 to 40 MPa and axial strains of 500 to 1000 microstrains. The stiffening of the rock in two boreholes (3 and 5) can be seen from the uniaxial test results. The explanation of this behaviour is not at present apparent because borehole 3 is located in the centre of the epicentral block while borehole 5 is located outside the epicentral block.

The effect of weathering and proximity to a known fault such as in the case of borehole 6 are inconclusive as well. There does not appear to be any significant and consistent increase with depth of sample unconfined compressive strength or Young's modulus. Some samples such as 3713-U1 taken near the surface exhibit a large hysteresis while other samples of the same rock type such as 3712-U1 also taken near the surface do not.

4.2 Group II

A total of 14 samples were tested for density, absorption and effective porosity. The individual test results are given in Table 6 and the arithmetic averages are given in Table 7. The

granite samples had the lowest densities ranging from 2600 to 2730 kg/m³ with effective porosities varying from 0.38% to 1.00% and absorptions varying from 0.14% to 0.37%. The diorite samples had the highest densities which varied from 2870 kg/m³ to 2910 kg/m³ while the granodiorites ranged from 2790 to 2840 kg/m³. The average effective porosities and absorptions for the diorites and granodiorites were the same. The range of values for the two rock types were:

	maximum		minimum	
	effective porosity(%)	absorption(%)	effective porosity(%)	absorption(%)
diorite	0.48	0.17	0.35	0.12
granodiorite	0.53	0.19	0.33	0.12

Mineralogy

Brief descriptions of each rock type are given below. Photographs of the thin section of each rock type are contained in Appendix 2.

4.2.1 Granodiorite (P3708)

Large (up to 10mm in diameter) phenocrysts of plagioclase that range in colour from white to pale pink are contained in a dark grey, medium grained groundmass of quartz, biotite plagioclase and hornblende. Occasional cluster of anhedral brown sphene crystals were observed as well.

Microscopic examination of a thin section of this material yielded the following approximate quantities of each mineral.

plagioclase	40%
perthite	25%
quartz	25%
biotite	5%
hornblende	5%
microcline	1%
sphene	trace
opaques(magnetite)	trace

There appears to be some alteration of the plagioclase crystals at the crystal edges to chlorite. Alteration products also appear as inclusions in the perthite crystals and at the edges of the perthite crystals. The microcline appears only as an inclusion in the plagioclase. The large feldspar grains appear to be euhedral to subhedral with the quartz and biotite growing around them. The biotite grains contain small intergrowths (probably) sphene that are surrounded by dark brown to black aureoles.

4.2.2 Diorite (P3710)

This is a dark grey, fine to medium grained rock composed of quartz, plagioclase, biotite and hornblende. There are a few small anhedral phenocrysts of reddish brown sphene throughout the rock. The approximate composition of the diorite as determined by microscopic examination is:

hornblende	35%
plagioclase	30%
biotite	20%
quartz	10%
alkali feldspar	5%
sphene	trace
opaques (magnetite)	trace

There is no apparent systematic distribution of the various mineral types. All mineral grains appear to be approximately the same size. The hornblende appears to be altering to biotite and chlorite while the feldspar crystals appear to be altering to chlorite/sericite. The alkali feldspars seem to be more altered than the plagioclase crystals. The biotite grains contain black aureoles as in the granodiorite.

4.2.3 Granite (P3712)

This is a coarse grained rock containing large pink plagioclase crystals as well as quartz, biotite and alkali feldspar. Occasional grains of sphene are also visible.

The microscopic examination revealed the following composition:

plagioclase	40%
quartz	25%
cordierite	15%
perthite	10%
biotite	10%
opaques (magnetite)	1%
sphene	trace

The feldspar crystals appear to be altering to sericite with the cordierite and perthite being more altered than the plagioclase. The more deeply altered feldspar grains tend to show a consistent fracture pattern that is not seen in the other mineral phases in the granite. This consistent fracturing pattern in the feldspar grains was not observed in either the granodiorite or diorite. There were occasional quartz grains that were fractured but there did not appear to be any coherent distribution pattern of these fractured grains nor pattern to the fracturing. The biotite crystals contain black aureoles probably due to sphene crystals.

4.3 Group III

The ultrasonic compressional (V_p) and shear wave (V_s) velocities were determined while the test specimens were under axial loads. The results of these tests are given in Tables 8 and 9. Only the velocities at gauge pressures of 1,6 and 11 MPa are reported as they represent the initial, mid and maximum loadings for each specimen. The actual stress applied to the specimen at gauge pressures of 1,6 and 11 MPa are different due to the geometry of the test and so the velocities in Tables 8 and 9 are reported as being taken at axial stresses of 1.39, 8.38 and 15.35 MPa. The dynamic elastic constants Young's modulus (E), shear modulus (G), bulk modulus (K) and Poisson's ratio (μ) for the applied axial stresses of 1.39, 8.38 and 15.35 MPa are reported in Tables 10 and 11. The range of values for each rock type is given in Table 12. The average values reported in Table 12 show that all three rock types show an increase in dynamic properties with increasing load. The granodiorite and diorite groups exhibit similar ranges of dynamic properties whereas the values for the granite are significantly lower. The diorite group can be divided into two separate groups as far as the dynamic test results are concerned. The diorite samples from boreholes 2 and 3 (sample groups 3709 and 3710) consistently show higher dynamic values than those from borehole 4 (sample group 3711). The reason for this behaviour is not known at present.

4.4 Group IV

The results of the individual triaxial tests are given in Table 13 while the axial strengths and average values for internal friction and cohesion for each specimen are given in Tables 14 and 15. Only one test specimen, 3708 TR11, was tested with a confining pressure of 20 MPa. This final test pressure run was discontinued in order to maintain time schedules. No results are reported for sample 3709 TR11 because a malfunction in the load system caused an instantaneous load to be applied to the sample and resulted in sample failure.

Carmichael (1982) and Hoek and Bray (1981) report some values for internal friction and cohesion of rock materials and it would appear that the apparent cohesion values obtained from the triaxial tests agree fairly well with the other values reported for similar rock types. The only exception to this is the granite sample 3712 TR12 which yielded a cohesion strength of 5 MPa. This could be an artificially low value caused by the large strength increase between the test run at 10 MPa and 15 MPa which caused the failure envelope for the 10 to 15 MPa pressure range to be steeply inclined. The reason for the sudden strength increase is not understood. The angles of internal friction for the Miramichi cores which range from 44° to 62° are higher than "typical" values reported in Hoek and Bray (1981) which are in the range of 30° to 35° . The axial strengths at 0 MPa confining

pressure reported in Tables 14 and 15 are uniaxial compressive strengths of the uniaxial sample which was closest to the triaxial specimen in the borehole. In most cases the unconfined and triaxial specimens were taken from the same length of core and should have minimal variation with respect to mineral composition, grain size and texture. In most cases, the uniaxial strengths are lower than the triaxial test strengths but in cases of samples 3709 TRi2 (granodiorite), 3710 TRi2 (diorite), 3711 TRi1 (diorite), and 3712 TRi1 (granite) the tests run at 5 MPa confining pressure were lower than the unconfined strength. A possible explanation for this behaviour could be the effect of residual stress locked into these samples. The presence of residual stress in the rock material could only be confirmed by testing methods which are beyond the scope of the present study. Originally, it was planned to obtain stress-strain curves for the triaxial compression tests but a system failure which was not detected until after testing made the stress-strain data unusable. This failure also made the extension test data unusable. It was planned to compare the extension test data to the direct tensile test data but this was not possible after the system failure was discovered.

4.5 Group V

The test results for the direct tensile tests are reported in Table 16 and the stress-strain curves are given in Appendix 3. Only ultimate strength results are reported for samples 3710 TDT and 3712 TDT as these cores were not strain gauged and were tested to get an estimate of the tensile strength of the rocks.

The strain gauged specimens were subjected to three load-unload cycles and the deformation moduli values reported are average values for the last two load cycles. The maximum strains at failure are those measured at the point at which the specimen began to fail. The failure strains for sample 3708 TD1 indicate expansion but may have been due to the onset of specimen failure affecting the strain gauges.

The deformation moduli as determined by the direct tensile method are much smaller than the Young's moduli values determined by unconfined compression testing. The samples 3711TD1 and 3711TD2 are classified as diorites even though they contained the large feldspar phenocrysts which is a characteristic of the granodiorite rock type. The log of borehole 4 and other samples nearby are diorites but it does indicate the extent to which these two rock types are intermingled. This relationship is also exhibited by the similarity of most of the other strength test results for the two rock types. The ratios of the tensile deformation modulus to the Young's modulus of the nearest compressive test sample(s) are given below:

Rock Type	Tensile Modulus (T) MPa	Young's Modulus (E) MPa	T/E	Poisson's Ratio
Granodiorite	8221	69412 ⁺	0.12	0.25 ⁺
Granodiorite	13646	71698	0.19	0.26
Diorite	17141	73455	0.23	0.24
Diorite	10605	75192	0.14	0.25
Diorite	6897	67196	0.10	0.22
Granite	15158	56699	0.27	0.22

⁺ average value of two tests

The ratio of the two moduli generally appears to be approximately the same as the Poisson's ratio for the unconfined compression tests. However, the variability of the diorite and granodiorite can be seen from the fact that there is a wide range in the T/E ratio which can vary from less than one half of the Poisson's ratio to nearly equal Poisson's ratio.

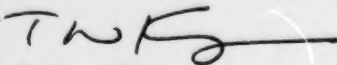
The tensile strengths determined by the direct test as shown in Table 16 were lower than those determined by the Brazilian test method which are given in Table 17 although the diorites cores gave nearly the same average strength result with 12.54 MPa for direct tests and 15.41 MPa for Brazilian tests. The average strengths for granite were 2.93 MPa (direct) and 10.62 MPa (Brazilian) while the granodiorites gave values of 7.66 MPa (direct) and 13.66 MPa (Brazilian). The average direct tensile strength for granodiorites does not include the result for sample 3708 TD1 which appears to be an exceptionally low value. More granodiorites were subjected to the Brazilian test than either of the granites or diorites because this rock type was the most variable with respect to grain size distribution and texture. The test results indicate that this visible variation does not appear to affect the rock strength.

5.0 SUMMARY

This series of tests performed on the cores from the epicentral area of the Miramichi series of earthquakes has provided some basic information on the physical parameters of the rock materials in the epicentral block. The explanation of the

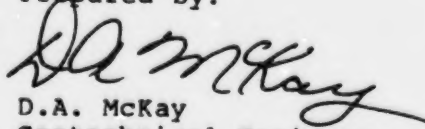
behaviour of some of the tests, such as the triaxial tests is not readily apparent and may have to be investigated further.

Approved by:



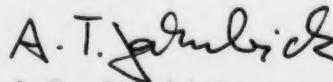
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TABLE 1
MIRAMICHI ROCK CORE TEST GROUPINGS
- ORIGINAL PLAN

Group	Type of Test	Parameters Obtained	Number of Tests
I	uniaxial testing	unconfined compressive strength Young's modulus of elasticity Poisson's ratio	28
II	density	density porosity absorption mineralogy	12
III	ultrasonic testing	compressional wave velocity shear wave velocity Young's modulus of elasticity shear modulus bulk modulus Poisson's ratio	40
IV	triaxial testing	triaxial compressive strength angle of internal friction apparent cohesion triaxial extension behaviour	12
V	tensile testing	direct tensile strength deformation modulus indirect tensile strength	6 15

TABLE 2
MIRAMICHI ROCK CORE TEST GROUPINGS
- FINAL NUMBER OF TESTS

Group	Number of Tests			Total Number of Tests
	Granodiorite	Diorite	Granite	
I	13	19	12	34
II	Density 6	4	4	14
	Mineralogy 1	1	1	3
III	20	15	19	54
IV	4	4	4	12
V	Direct 3	2	3	8
	Brazilian 9	2	4	15

TABLE 3

MIRANICHI ROCK CORE TESTS
UNCONFINED COMPRESSIVE STRENGTH TESTS
BOREHOLES 1 AND 2

Sample No	BH	Depth m	Rock Type	Dia mm	Length mm	L/D	Failure+ Mode	Load Rate kN/MIN	Young's Modulus MPa	Poisson's Ratio	Compressive Strength MPa
3708U1	1	3.78	Grano-Diorite	63.37	159.70	2.52	SH	30	71,617	0.23	173.43
3708U2	1	12.86	"	63.38	160.46	2.53	SH/SP	30	67,206	0.27	106.18
3708U3	1	16.60	"	63.35	160.73	2.54	C/SP	30	66,613	0.23	180.20
3708U4	1	22.22	"	63.40	159.97	2.52	C	30	74,532	0.24	205.58
3708U5	1	29.38	"	63.41	156.50	2.47	C/SP	30	74,020	0.27	189.05
3709U1	2	2.38	"	63.08	159.21	2.52	C	30	68,388	0.24	172.79
3709U2	2	8.18	"	63.41	160.71	2.53	C	30	75,498	0.27	176.38
3709U3	2	11.11	"	63.45	161.50	2.55	C/SH	22	65,485	0.20	126.50
3709U4	2	17.28	"	63.45	160.48	2.53	SP	30	72,976	0.23	179.00
3709U5	2	25.38	"	63.40	161.73	2.55	C/SH	30	71,698	0.26	177.39
3709U6	2	29.42	Diorite	63.38	158.75	2.50	C	30	82,140	0.25	192.71

+SH = shearing

SP = splitting

C = conical

TABLE 4

MIRAMICHI ROCK CORE TESTS
UNCONFINED COMPRESSIVE STRENGTH TESTS
BOREHOLES 3 AND 4

Sample No	BH	Depth m	Rock Type	Dia mm	Length mm	L/D	Failure+ Mode	Load Rate kN/MIN	Young's Modulus MPa	Poisson's Ratio	Compressive Strength MPa
3710U1	3	1.75	Grano-Diorite	63.29	157.99	2.50	C	30	69,180	0.26	176.10
3710U2	3	2.23	Diorite	63.32	157.98	2.50	C	30	76,911	0.25	236.58
3710U3	3	7.27	Grano-Diorite	63.45	141.50	2.23	C	30	77,121	0.25	178.69
3710U4	3	16.87	Diorite	63.35	160.72	2.54	C	22	74,513	0.20	236.36
3710U5	3	17.66	"	63.31	160.48	2.53	C	30	73,455	0.24	227.13
3710U6	3	29.02	Grano-Diorite	63.30	155.48	2.46	C	30	70,149	0.27	179.85
3711U1	4	1.52	Granite	63.22	158.75	2.51	C	22	47,690	0.19	152.37
3711U2	4	5.63	Diorite	63.45	155.85	2.46	C	30	65,762	0.25	231.82
3711U3	4	9.50	"	63.40	159.80	2.52	C/SH	30	75,192	0.25	252.14
3711U4	4	14.48	"	63.45	159.75	2.52	C/SP	30	67,196	0.22	199.24
3711U5	4	24.28	"	63.50	159.25	2.51	C/SP	30	101,429	0.39	209.35 Healed Fracture
3711U6	4	28.48	"	63.25	160.54	2.54	C/SP	30	76,055	0.23	234.56

+SH = shearing

SP = splitting

C = conical

TABLE 5
MIRAMICHI ROCK CORE TESTS
UNCONFINED COMPRESSIVE STRENGTH TESTS
BOREHOLES 5 AND 6

Sample No	BH	Depth m	Rock Type	Dia mm	Length mm	L/D	Failure+ Mode	Load Rate kN/MIN	Young's Modulus MPa	Poisson's Ratio	Compressive Strength MPa
3712U1	5	0.71	Granite	63.35	160.00	2.53	SH/SP	22	53,549	0.22	159.58
3712U2	5	9.09	"	63.24	160.72	2.54	SH/SP	22	62,091	0.21	164.91
3712U3	5	16.34	"	63.37	159.26	2.51	C	22	59,632	0.18	178.51
3712U4	5	24.71	"	63.31	154.05	2.43	C	30	68,919	0.25	170.58
3712U5	5	28.96	"	63.16	157.58	2.49	C	30	69,465	0.27	170.12
3713U1	6	0.04	"	63.20	157.31	2.49	C	30	45,510	0.28	164.17
3713U2	6	6.08	"	63.23	156.51	2.48	C	30	51,976	0.27	171.97
3713U3	6	16.72	"	64.11	156.30	2.48	C	30	53,140	0.23	168.47
3713U4	6	17.99	"	63.10	146.09	2.32	C	30	56,699	0.22	209.78
3713U5	6	23.75	"	63.27	158.08	2.50	C/SH	30	47,984	0.29	146.95
3713U6	6	29.76	"	63.25	154.24	2.44	C	30	38,412	0.24	151.18

+SH = shearing

SP = splitting

C = conical

TABLE 6

MIRAMICHI ROCK CORE TESTS
INDIVIDUAL DENSITY, ABSORPTION, AND POROSITY TEST RESULTS

Sample No	BH	Depth m	Rock Type	Density kg/m ³	Absorption %	Effective Porosity %
3708D1	1	13.24	Grano- Diorite	2820	0.13	0.37
3708D2	1	16.59	"	2790	0.13	0.36
3709D1	2	11.10	"	2840	0.19	0.53
3709D2	2	25.37	"	2840	0.12	0.33
3710D1	3	2.22	Diorite	2880	0.15	0.43
3710D2	3	23.47	"	2870	0.12	0.35
3710D3	3	2.20	"	2880	0.16	0.45
3711D1	4	14.67	Grano- Diorite	2840	0.17	0.48
3711D2	4	24.44	"	2810	0.18	0.52
3711D3	4	28.47	Diorite	2910	0.17	0.48
3712D1	5	0.90	Granite	2730	0.20	0.55
3712D2	5	16.62	"	2720	0.14	0.38
3713D1	6	6.07	"	2680	0.35	0.95
3713D2	6	29.64	"	2700	0.37	1.00

TABLE 7

MIRAMICHI ROCK CORE TESTS
AVERAGE DENSITY, ABSORPTION, AND POROSITY VALUES

Rock Type	No of Samples	Density kg/m ³	Absorption %	Effective Porosity %
Granodiorite	6	2823	0.15	0.43
Diorite	4	2885	0.15	0.43
Granite	4	2708	0.27	0.72

TABLE 8

MIRAMICHI ROCK CORE TESTS - V_C AND V_S TEST RESULTS

Sample Number	Borehole	Depth m	Rock Type	Length mm	Diameter mm	Length to Diameter Ratio	Axial Stress			
							1.39 MPa		8.38 MPa	
							V_C (m/sec)	V_S (m/sec)	V_C (m/sec)	V_S (m/sec)
3708 TRI 1	1	13.25	Granodiorite	156.00	63.38	2.46	4333	2108	4522	2152
3708 TRI 2	1	29.13	"	155.93	63.40	2.46	4331	2052	4586	2166
3708 U1	1	3.78	"	159.70	63.37	2.52	4203	2061	4563	2144
3708 U2	1	12.86	"	160.46	63.38	2.53	4719	2125	4937	2260
3708 U3	1	16.60	"	160.73	63.36	2.54	3969	1997	4344	2101
3708 U4	1	22.22	"	159.97	63.40	2.52	4383	2091	4775	2206
3708 U5	1	29.38	"	156.50	63.41	2.47	4013	1932	4347	2101
3709 TRI 1	2	8.48	"	156.70	63.44	2.47	4609	2147	4897	2192
3709 TRI 2	2	29.26	"	155.47	63.37	2.45	5361	2320	5553	2356
3709 U1	2	2.38	"	159.21	63.08	2.52	4135	1990	4615	2123
3709 U2	2	8.18	"	160.71	63.41	2.53	4727	2592	4945	2635
3709 U3	2	11.11	"	161.50	63.45	2.54	4549	2168	4821	2228
3709 U4	2	17.28	"	160.48	63.45	2.53	4521	2154	4790	2214
3709 U5	2	25.38	"	161.73	63.40	2.55	4757	2361	4901	2412
3709 U6	2	29.42	Diorite	158.75	63.38	2.50	5474	2520	5570	2560
3710 TRI 1	3	7.11	"	138.21	63.40	2.18	5316	2194	5528	2211
3710 TRI 2	3	17.27	"	160.00	63.35	2.53	5517	2520	5517	2520
3710 U1	3	1.75	Granodiorite	157.99	63.29	2.50	4579	2150	4861	2225
3710 U2	3	2.23	Diorite	157.98	63.32	2.49	5096	2678	5266	2701
3710 U3	3	7.27	Granodiorite	141.50	63.45	2.23	5054	2670	5241	2721
3710 U4	3	16.87	"	160.72	63.35	2.54	5542	2551	5639	2551
3710 U5	3	17.66	Diorite	160.48	63.31	2.53	5349	2343	5440	2527
3710 U6	3	29.02	Granodiorite	155.48	63.30	2.46	4859	2704	5015	2776
									4952	2197
									4873	2212
									4839	2115
									5176	2292
									4659	2172
									4999	2253
									4672	2174
									5138	2239
									5653	2392
									4899	2181
									5184	2724
									5047	2410
									5015	2260
									5217	2469
									5670	2602
									5528	2229
									5614	2540
									5096	2323
									5355	2747
									5340	2775
									5740	2572
									5534	2547
									5271	2827

TABLE 9
MIRAMICHI ROCK CORE TESTS - V_C AND V_S TEST RESULTS

Sample Number	Borehole	Depth m	Rock Type	Length mm	Diameter mm	Length to Diameter Ratio	1.39 MPa		8.38 MPa		15.35 MPa	
							V_C (m/sec)	V_S (m/sec)	V_C (m/sec)	V_S (m/sec)	V_C (m/sec)	V_S (m/sec)
3711 TRI 1	4	5.47	Diorite	156.98	63.40	2.48	4186	1962	4361	1987	4550	2013
3711 TRI 2	4	24.55	"	160.08	63.48	2.52	4002	1964	4105	2001	4386	2039
3711 U1	4	1.52	Granite	158.75	63.22	2.51	3608	1707	4291	1846	4536	2009
3711 U2	4	5.63	Diorite	155.85	63.45	2.46	4156	2309	4390	2398	4584	2398
3711 U3	4	9.50	"	159.80	63.40	2.52	4566	2517	4700	2557	4842	2620
3711 U4	4	14.48	"	159.75	63.45	2.52	4149	2477	4318	2556	4564	2619
3711 U5	4	24.28	"	159.25	63.50	2.51	3792	1896	4032	1930	4304	1978
3711 U6	4	28.48	"	160.54	63.25	2.54	4792	2589	4865	2632	5017	2654
3712 TRI 1	5	9.64	Granite	158.80	63.28	2.51	3873	1795	4537	2335	4886	2501
3712 TRI 2	5	28.80	"	155.23	63.15	2.46	3786	1758	4312	1940	4704	2016
3712 U1	5	0.71	"	160.00	63.35	2.53	3902	1758	4444	1928	4706	2000
3712 U2	5	9.09	"	160.72	63.24	2.54	3738	1607	4592	1913	5023	1984
3712 U3	5	16.34	"	159.26	63.37	2.51	3884	1810	4424	1991	4550	2243
3712 U4	5	24.71	"	154.05	63.31	2.43	3950	1856	4401	2027	5135	2027
3712 U5	5	28.96	"	157.58	63.16	2.49	4041	1854	4502	2020	4924	2101
3713 TRI 1	6	0.20	"	156.30	63.20	2.47	3473	1628	4113	1839	4466	1906
3713 TRI 2	6	23.91	"	158.30	63.28	2.50	3231	1567	3681	2435	4166	2638
3713 U1	6	0.04	"	157.31	63.20	2.49	2913	1457	4034	1808	4370	1918
3713 U2	6	6.08	"	156.51	63.23	2.48	3069	1614	4230	1886	4348	1956
3713 U3	6	16.72	"	156.30	63.11	2.48	4342	2316	4736	2461	5042	2501
3713 U4	6	17.99	"	146.09	63.10	2.32	4427	1922	5038	2029	5218	2058
3713 U5	6	23.75	"	158.08	63.27	2.50	3162	1565	3676	1756	4053	1860
3713 U6	6	29.76	"	154.24	63.25	2.44	2804	1390	3587	1574	4059	1695

TABLE 10
MIRAMICHI ROCK CORE TESTS - DYNAMIC ELASTIC CONSTANTS

Sample Number	1.39 MPa						8.38 MPa						15.35 MPa					
	E			G			E			G			E			G		
	MPa	MPa	K	MPa	MPa	K	MPa	MPa	K	MPa	MPa	K	MPa	MPa	K	MPa	MPa	K
3708 TRI 1	33736	12541	36269	0.34	35372	13066	40278	0.35	37532	13624	51048	0.38						
3708 TRI 2	32201	11879	37104	0.36	35909	13236	41707	0.36	37833	13805	48600	0.37						
3708 U1	32156	11983	33865	0.34	35230	12967	41463	0.36	34897	12626	49256	0.38						
3708 U2	34997	12747	45858	0.37	39420	14414	49572	0.37	40868	14828	55837	0.38						
3708 U3	29938	11250	29447	0.33	33568	12457	36644	0.35	36243	13313	43500	0.36						
3708 U4	33383	12340	37753	0.35	37488	13739	46031	0.36	39325	14326	51423	0.37						
3708 U5	28424	10535	31396	0.35	33565	12453	36727	0.35	36315	13333	43811	0.36						
3709 TRI 1	35407	13003	42605	0.36	37268	13554	49597	0.37	39111	14142	55634	0.38						
3709 TRI 2	42082	15195	60846	0.38	43540	15659	66124	0.39	44914	16144	68670	0.39						
3709 U1	30162	11177	33356	0.35	34737	12717	43142	0.37	36951	13423	49825	0.38						
3709 U2	48728	18961	37769	0.28	50999	19588	42887	0.30	54830	20938	47926	0.31						
3709 U3	35888	13261	40722	0.35	38208	14003	46915	0.36	44344	16397	50017	0.35						
3709 U4	35437	13094	40210	0.35	37727	13827	46325	0.36	39577	14417	51751	0.37						
3709 U5	42051	15731	42878	0.34	44063	16443	45857	0.34	46649	17205	53869	0.36						
3709 U6	50026	18317	62022	0.37	51671	18913	64288	0.37	53398	19538	66680	0.37						
3710 TRI 1	38801	13884	63004	0.40	39633	14107	69358	0.40	40222	14335	69054	0.40						
3710 TRI 2	50118	18315	63392	0.37	50118	18315	63392	0.37	51032	18607	66111	0.37						
3710 U1	35432	13039	41795	0.36	38216	13973	48057	0.37	41704	15233	52987	0.37						
3710 U2	54161	20683	47342	0.31	55607	21038	51946	0.32	57549	21776	53697	0.32						
3710 U3	52557	20115	45250	0.31	54975	20896	49646	0.32	57136	21723	51495	0.32						
3710 U4	51276	18774	63571	0.37	51493	18774	66708	0.37	52438	19076	69611	0.37						
3710 U5	43742	15833	61437	0.38	50204	18425	60804	0.36	51123	18718	63382	0.37						
3710 U6	52642	20633	39109	0.28	55649	21754	41983	0.28	59547	22552	48321	0.30						

TABLE 11
MIRAMICHI ROCK CORE TESTS - DYNAMIC ELASTIC CONSTANTS

Sample Number	1.39 MPa						8.38 MPa						15.35 MPa					
	E			K			E			K			E			K		
	MPa	G	MPa	MPa	μ	MPa	MPa	G	MPa	MPa	μ	MPa	MPa	G	MPa	MPa	μ	MPa
P-3711 TRI 1	30195	11108	35742	35742	0.36	31186	11391	39665	39665	0.37	32212	11684	44146	44146	0.38			
P-3711 TRI 2	29856	11129	31363	31363	0.34	31051	11551	33201	33201	0.34	32680	11996	39493	39493	0.36			
P-3711 U1	21374	7882	24705	24705	0.36	25560	9218	37509	37509	0.39	30104	10924	41088	41088	0.38			
P-3711 U2	39270	15379	29322	29322	0.28	42703	16584	33487	33487	0.29	43506	16584	38501	38501	0.31			
P-3711 U3	46835	18269	35776	35776	0.28	48648	18858	38580	38580	0.29	51200	19797	41249	41249	0.29			
P-3711 U4	43293	17696	26073	26073	0.22	46371	18847	28647	28647	0.23	49644	19785	33718	33718	0.25			
P-3711 U5	27649	10368	27649	27649	0.33	29050	10749	32558	32558	0.35	30845	11290	38387	38387	0.37			
P-3711 U6	50050	19342	40461	40461	0.29	51676	19981	41632	41632	0.29	53048	20313	45523	45523	0.31			
P-3712 TRI 1	22616	8238	29598	29598	0.37	38942	14753	36018	36018	0.32	44750	16918	42028	42028	0.32			
P-3712 TRI 2	23612	8712	27162	27162	0.36	37970	10185	36717	36717	0.37	30509	10994	45199	45199	0.39			
P-3712 U1	22959	8363	30047	30047	0.37	27829	10053	40033	40033	0.38	30077	10821	45480	45480	0.39			
P-3712 U2	19378	6988	28475	28475	0.39	27630	9903	43839	43839	0.39	29982	10651	54040	54040	0.41			
P-3712 U3	24124	8860	29004	29004	0.36	29441	10721	38648	38648	0.37	36464	13611	37863	37863	0.34			
P-3712 U4	25316	9319	29783	29783	0.36	30352	11115	37587	37587	0.37	31293	11115	56512	56512	0.41			
P-3712 U5	25413	9297	31768	31768	0.37	30340	11041	40115	40115	0.37	31688	11942	49677	49677	0.39			
P-3713 TRI 1	19493	7171	23075	23075	0.36	25156	9147	33571	33571	0.38	27296	9829	40844	40844	0.39			
P-3713 TRI 2	17891	6645	19373	19373	0.35	35649	16045	15270	15270	0.11	43879	18830	21838	21838	0.17			
P-3713 U1	15305	5739	15305	15305	0.33	24309	8845	32221	32221	0.37	27491	9956	38380	38380	0.38			
P-3713 U2	18438	7043	16086	16086	0.31	26471	9619	35579	35579	0.38	28433	10354	37325	37325	0.37			
P-3713 U3	37749	14505	31654	31654	0.30	43105	16390	38833	38833	0.32	45235	16918	46212	46212	0.34			
P-3713 U4	27665	9996	39689	39689	0.38	31255	11137	53801	53801	0.40	32250	11453	58371	58371	0.41			
P-3713 U5	17729	6627	18205	18205	0.34	22569	8346	25433	25433	0.35	25575	9157	31970	31970	0.37			
P-3713 U6	13970	5223	14311	14311	0.34	18505	6701	25872	25872	0.38	21674	7772	34206	34206	0.39			

TABLE 12

MIRAMICHI ROCK TESTS
SUMMARY OF DYNAMIC TEST RESULTS

Rock Type	1.39 MPa			8.38 MPa			15.35 MPa			Dynamic Parameter
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	
Granodiorite	3969	5361	4535	4344	5553	4807	4659	5653	5061	V _C (m/sec)
Diorite	3792	5542	4764	4032	5639	4902	4034	5740	5053	
Granite	2804	4427	3638	3587	5038	4287	4053	5218	4637	
Granodiorite	1932	2704	2213	2101	2776	2041	2115	2827	2354	V _s (m/sec)
Diorite	1896	2589	2348	1930	2701	2395	1978	2747	2428	
Granite	1390	2316	1724	1574	2461	1987	1695	2638	2088	
Granodiorite	28424	52642	37366	33565	55649	40349	34897	58547	42752	E (MPa)
Diorite	27649	54161	42713	29050	55607	44570	30845	57549	46069	
Granite	13970	37749	22065	18505	43105	29068	21674	45235	32386	
Granodiorite	10535	20633	13970	12453	21754	14985	12626	22552	15766	G (MPa)
Diorite	11108	20683	16374	11391	21038	16733	11290	21776	17192	
Granite	5223	14505	8163	6701	16390	10826	7772	18830	11965	
Granodiorite	29447	60846	39778	36644	66124	45468	43811	68670	51410	K (MPa)
Diorite	26073	63571	49020	28647	69358	48020	33718	69611	51504	
Granite	14311	39689	25515	15270	53801	35690	21838	58371	42565	
Granodiorite	0.28	0.38	0.34	0.28	0.39	0.35	0.30	0.39	0.36	μ
Diorite	0.22	0.40	0.33	0.23	0.40	0.33	0.25	0.40	0.34	
Granite	0.30	0.39	0.35	0.11	0.40	0.38	0.17	0.41	0.37	

TABLE 13

MIRAMICHI ROCK CORE TESTS
INDIVIDUAL TRIAXIAL TEST RESULTS

Sample	BH	Depth m	Internal Friction Angle, ϕ (Degrees) Pressure Range (MPa)				Apparent Cohesion, C (MPa) Pressure Range				Average Values	
											ϕ	C
			0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20		
3708TRi1	1	13.25	50	59	62	-	34	21	13	-	57	23
3708TRi2	1	29.13	34	45	52	46	61	45	30	43	44	45
3709TRi1	2	8.48	-	-	-	-	-	-	-	-	NO	TEST
3709TRi2	2	29.26	59	59	59	-	16	16	16	-	59	16
3710TRi1	3	7.11	62	-	NO TEST	-	15	-	-	-	62	15
3710TRi2	3	17.27	57	57	57	-	24	24	24	-	57	24
3711TRi1	4	5.47	54	54	48	-	15	15	24	-	52	18
3711TRi2	4	24.55	57	48	46	-	30	43	43	-	50	39
3712TRi1	5	9.64	47	60	70	-	18	7	-9	-	59	5
3712TRi2	5	28.80	42	48	52	-	37	30	24	-	47	30
3713TRi1	6	0.20	56	56	55	-	26	27	27	-	56	27
3713TRi2	6	23.91	61	59	56	-	10	13	18	-	59	14

TABLE 14

MIRAMICHI ROCK CORE TESTS

SUMMARY OF TRIAXIAL TEST RESULTS

Sample No	BH	Depth m	Rock Type	Dia mm	Length mm	L/D	Load Rate kN/MIN	Failure Mode	Confining Pressure MPa	Axial Strength MPa	Apparent Cohesion (MPa)	Internal Friction Angle (Degrees)
3708U2	1	12.86	Granodiorite	63.38	160.46	2.53	30	SH/SP	0	106.18	23	57
3708TR11	1	13.25	"	63.38	156.00	2.46	10	SH	5 10 15	229.16 268.15 333.44		
3708U5	1	29.38	"	63.41	156.50	2.47	30	C/SP	0	189.05	45	44
3708TR11	1	29.13	"	63.40	155.93	2.46	10	SH	5 10 15 20	246.50 263.12 311.42 329.61		
3709U2	2	8.18	"	63.41	160.71	2.53	30	C	0	176.38	No Test	No Test
3709TR11	2	8.48	"	63.44	156.70	2.47	10	SH	5 10 15	" " "		
3709U6	2	29.42	"	63.38	158.75	2.50	30	C	0	192.71	16	59
3709TR12	2	29.26	"	63.37	155.47	2.45	10	SH	5 10 15	182.52 253.65 320.23		
3710U3	3	7.27	Diorite	63.45	141.50	2.23	30	C	0	178.69	15	62
3710TR11	3	7.11	"	63.40	138.21	2.18	10	SH	5 10 15	275.27 384.43 No Test		
3710U5	3	17.66	"	63.31	160.48	2.53	30	C	0	227.13	24	57
3710TR12	3	17.27	"	63.35	160.00	2.53	10	SH	5 10 15	213.83 269.67 333.76		

+ Average Value

TABLE 15

MIRAMICHI ROCK CORE TESTS
SUMMARY OF TRIAXIAL TEST RESULTS

Sample No	BH	Depth m	Rock Type	Dia mm	Length mm	L/D	Load Rate kN/MIN	Failure Mode	Confining Pressure MPa	Axial Strength MPa	Apparent Cohesion (MPa)	Internal Friction Angle (Degrees)
3711U2	4	5.63	Diorite	63.45	155.85	2.46	30	C	0	231.82	18	52
3711TRI1	4	5.47	"	63.40	156.98	2.48	10	SH	5 10 15	143.81 201.78 232.19		
3711U5	4	24.28	"	63.50	159.25	2.51	30	C/SP	0	209.35	39	50
3711TRI2	4	24.55	"	63.48	160.08	2.52	10	SH	5 10 15	259.65 308.92 348.02		
3712U2	5	9.09	Granite	63.24	160.72	2.54	22	SH/SP	0	164.91	5	59
3712TRI1	5	9.64	"	63.28	158.80	2.51	10	SH	5 10 15	131.64 171.06 273.45		
3712U5	5	28.96	"	63.16	157.58	2.49	30	C	0	170.12	30	47
3712TRI2	5	28.80	"	63.15	155.23	2.46	10	SH	5 10 15	192.52 216.79 259.25		
3713U1	6	0.04	"	63.20	157.31	2.49	30	C	0	164.17	27	56
3713TRI1	6	0.20	"	63.20	156.30	2.47	10	SH	5 10 15	228.24 284.02 334.07		
3713U5	6	23.75	"	63.27	158.08	2.50	30	C/SH	0	146.95	14	59
3713TRI2	6	23.91	"	63.28	158.30	2.50	10	SH	5 10 15	151.99 224.48 272.49		
+ Average Value												

TABLE 16

MIRAMICHI ROCK CORE TESTS
DIRECT TENSILE TEST RESULTS

Sample No	BH	Depth m	Rock Type	Dia mm	Length mm	Load Rate kN/MIN	Failure+ Location mm	Ult Tensile Strength MPa	Maximum* Axial $\mu\epsilon$	Strain Circum $\mu\epsilon$	Tensile ^x Modulus MPa
3708TD1	1	7.27	Granodiorite	63.37	138.20	90	70.0	0.71	1033	-177.6	8221
3709TD1	2	25.58	"	63.40	157.29	90	100.0	7.05	5430	53.4	13646
3710TD1	3	17.97	Diorite	63.35	158.47	90	100.0	12.79	1908	97.5	17141
3711TD1	4	9.66	"	63.42	152.02	90	150.0	8.89	1050	58.2	10605
3711TD2	4	14.28	"	63.44	157.00	90	130.0	7.04	1020	51.0	6897
3713TD1	6	18.14	Granite	63.10	158.22	90	115.0	3.53	250.7	5.79	15158
3710TDT	3	17.50	Diorite	63.35	160.05	90	100.0	12.28	-	-	-
3712TDT	5	16.63	Granite	63.37	161.72	90	110.0	2.33	-	-	-

+ Distance from lower platten

* At failure

x Average value

TABLE 17

MIRAMICHI ROCK CORE TESTS
BRAZILIAN TENSILE TEST RESULTS

Sample No	BH	Depth m	Rock Type	Dia mm	Length mm	L/D	Load Rate kN/MIN	Failure Mode	Tensile Strength MPa
3708B1	1	1.33	Granodiorite	63.36	33.35	0.53	0.004	SP	15.00
3708B2	1	3.94	"	63.36	33.71	0.53	0.004	SP	10.74
3708B3	1	4.06	"	63.33	34.28	0.54	0.004	SP	11.27
3709B1	2	25.55	"	63.41	32.71	0.52	0.004	SP	15.30
3709B2	2	25.74	"	63.42	33.06	0.52	0.004	SP	14.86
3710B1	3	1.62	Granite	63.26	32.21	0.51	0.004	SP	10.87
3710B2	3	17.04	Diorite	63.34	32.65	0.52	0.004	SP	13.12
3710B3	3	17.34	"	63.33	31.47	0.50	0.004	SP	17.70
3711B1	4	9.84	Granodiorite	63.39	32.25	0.51	0.004	SP	14.72
3711B2	4	14.25	"	63.45	32.75	0.52	0.004	SP	14.19
3711B3	4	14.44	"	63.44	31.52	0.50	0.004	SP	13.91
3711B4	4	14.64	"	63.42	32.63	0.51	0.004	SP	12.96
3712B1	5	0.98	Granite	63.35	33.03	0.52	0.004	SP	8.46
3713B1	6	16.69	"	63.13	31.53	0.50	0.004	SP	10.78
3713B2	6	18.30	"	63.08	33.59	0.53	0.004	SP	12.38

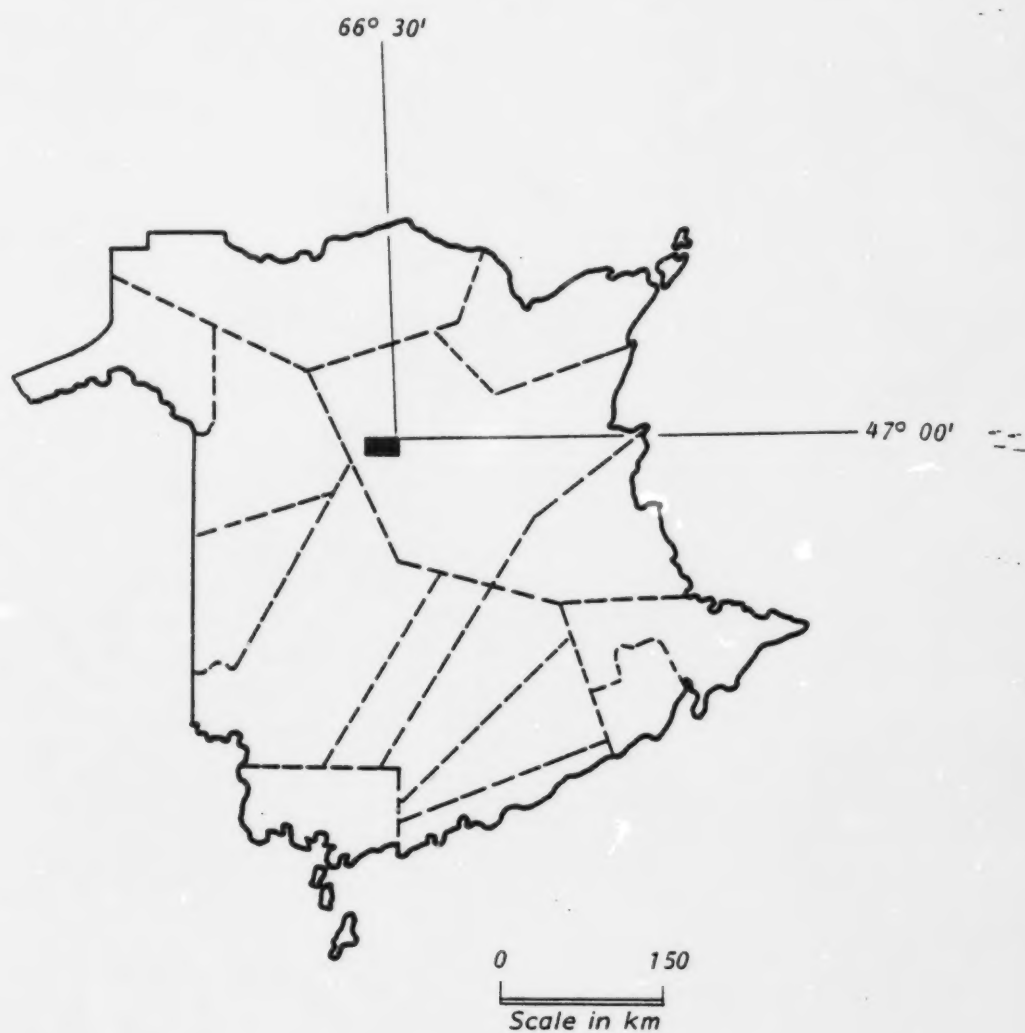


FIGURE 1
LOCATION OF STUDY AREA

1-800-4-A-ARTIST
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GEOLOGY of the MIRAMICHI EPICENTRAL REGION

After L.R. Goffe, 1962, 1979, 1972; G.W. Coates, 1979
(196) ACCIDENTARY SPINER PILE (REPORT NOS. 83-1)

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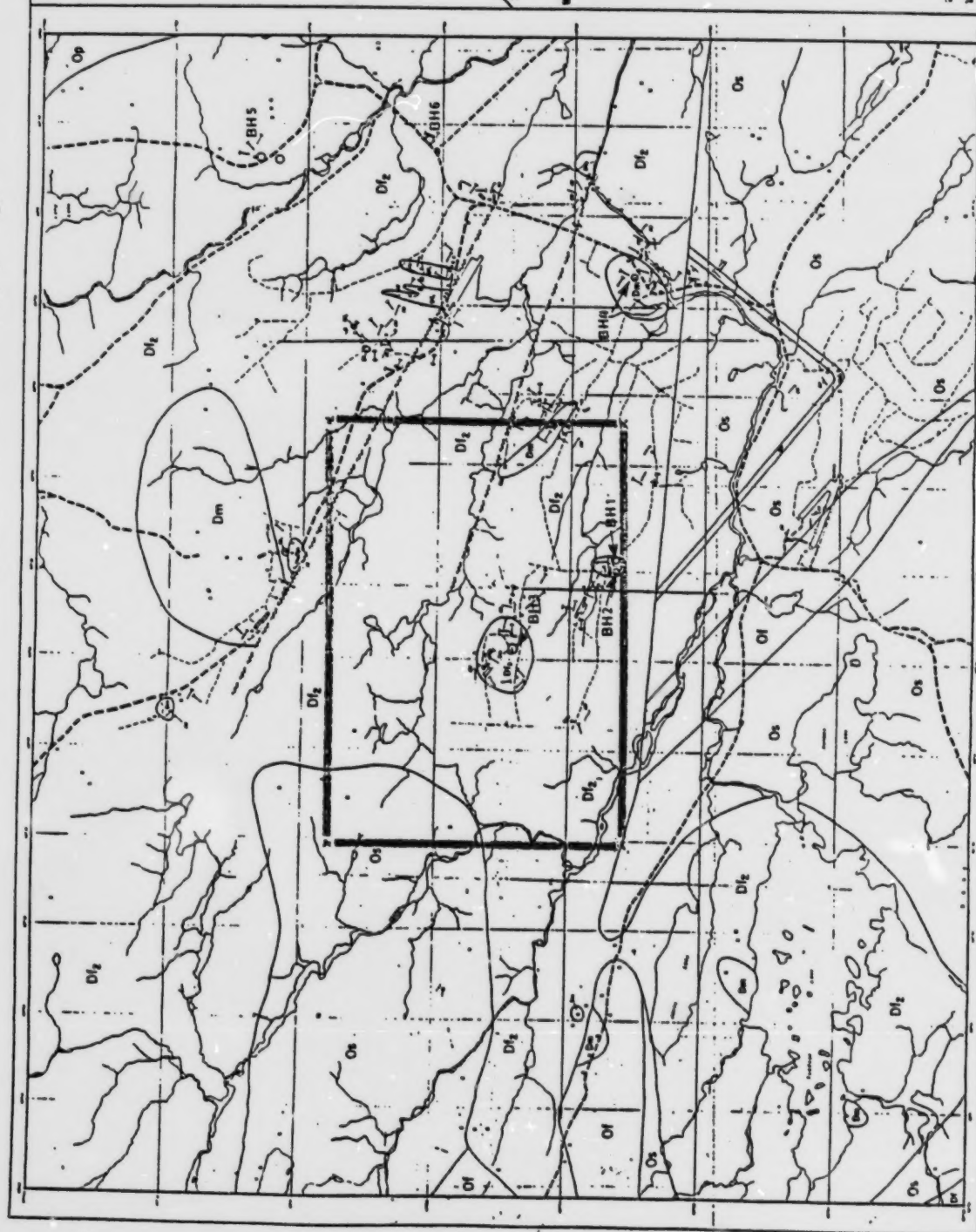
Only the young swimming group, swimming against the current in the river, was able to swim. The young swimming group, swimming against the current in the river, was able to swim. The young swimming group, swimming against the current in the river, was able to swim.

FIG. 2
OPEN FILE REPORT 83-31
PLATE 83-5



1

200150-RD



**Key
Geology**



Medium Grained, Dary Grey Diorite



Coarse Grained Light Grey Granodiorite



Coarse Grained, Light Pink Biotite Granite

Fractures



Material Joint or Fracture in Rock Core



Heavily Fractured Zone



No Core Recovered

**Overcore
Tests**



5.89 ← *Stress P (MPa)*

← *Test Number*

0.93 ← *Stress Q (MPa)*

← *Compressive Stress*

→ *Tensile Stress*

16 *No Test - Test Attempted at this Location but was Unsuccessful*

Laboratory Tests

U - Unconfined Compression Test

D - Density, Absorption, Porosity

TRi - Triaxial Test

TD - Direct Tensile Test

B - Brazilian Tensile Test

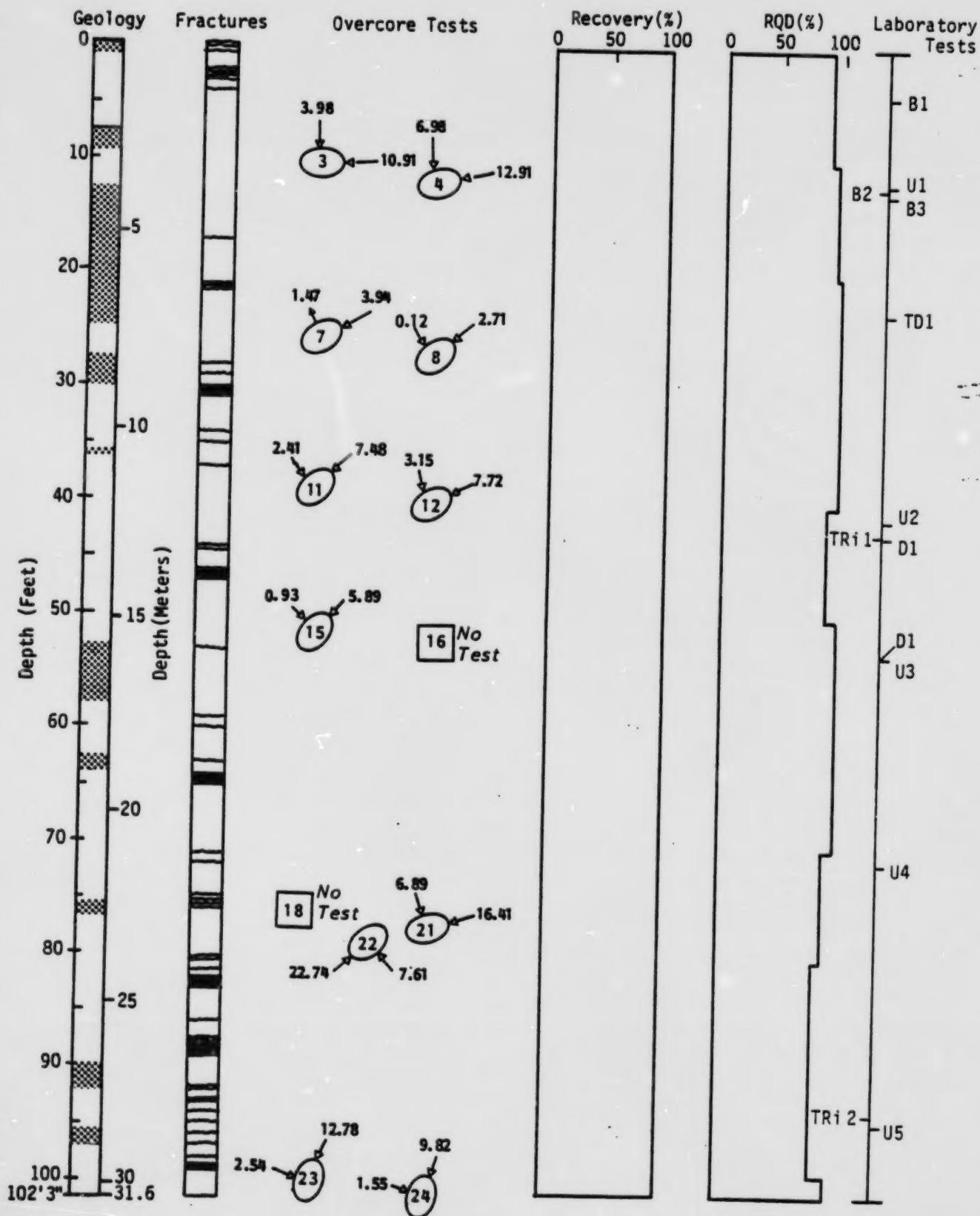


FIGURE 3
BOREHOLE 1 (BH1)

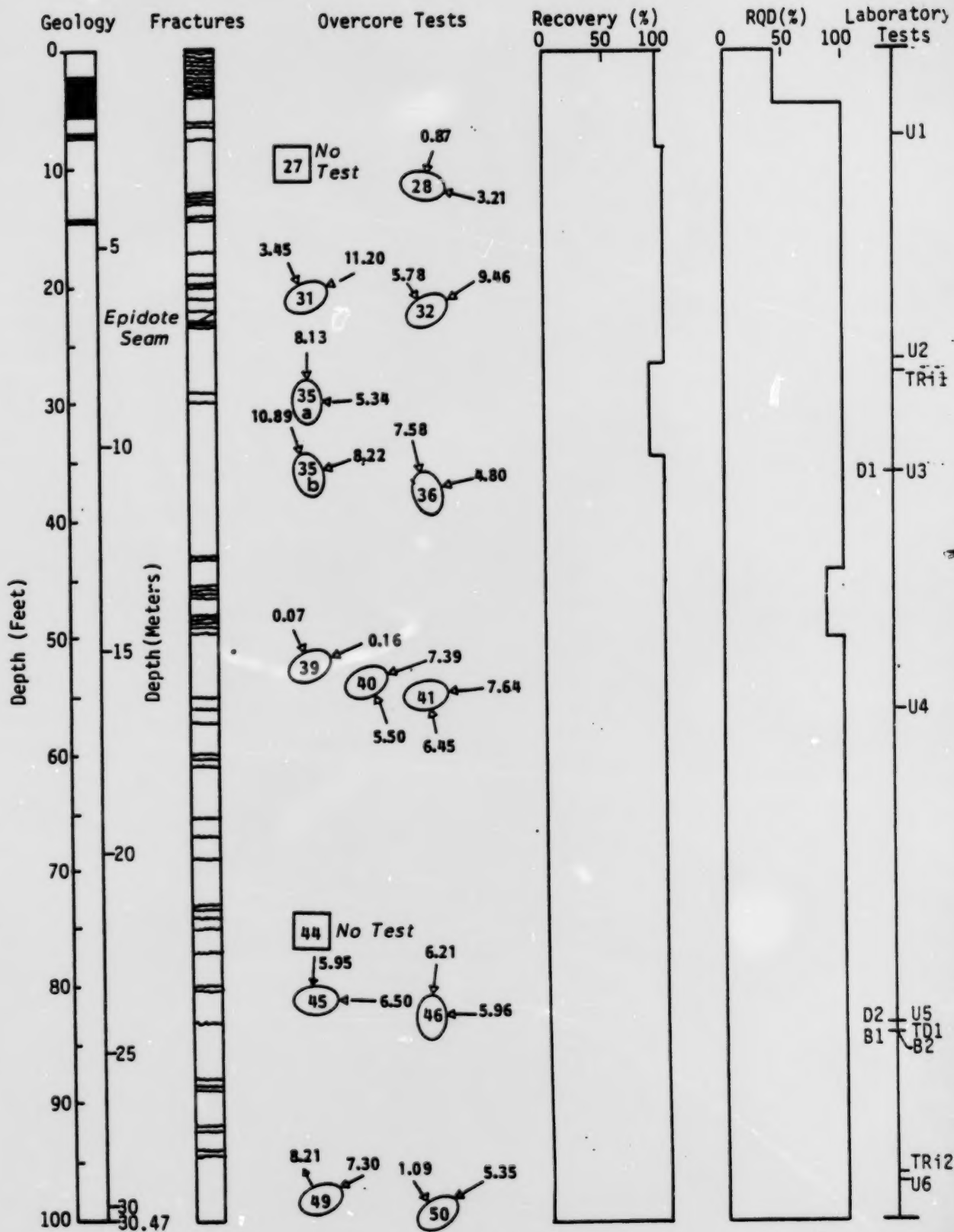


FIGURE 4
BOREHOLE 2 (BH2)

169325 RD

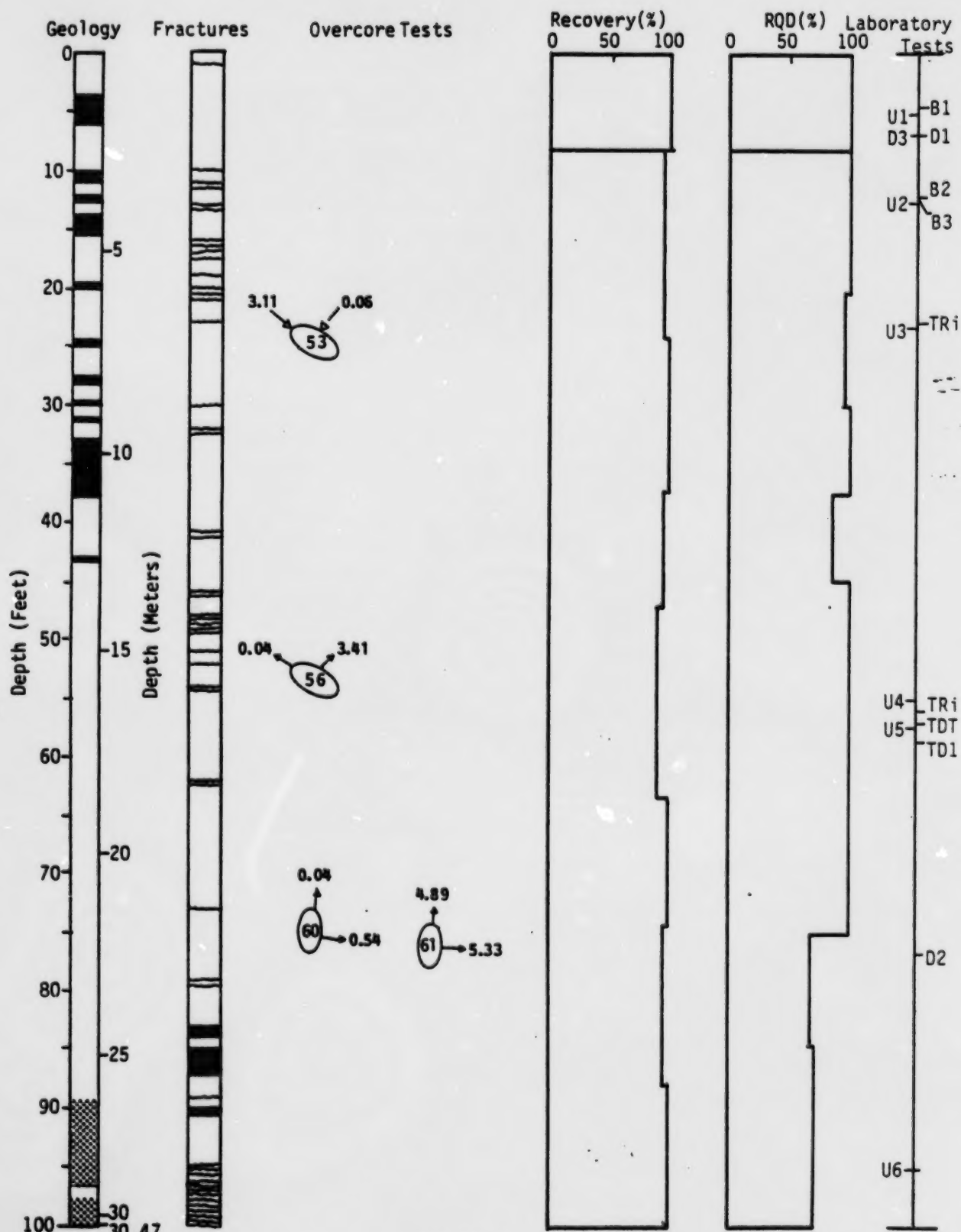


FIGURE 5
BOREHOLE 3 (BH3)

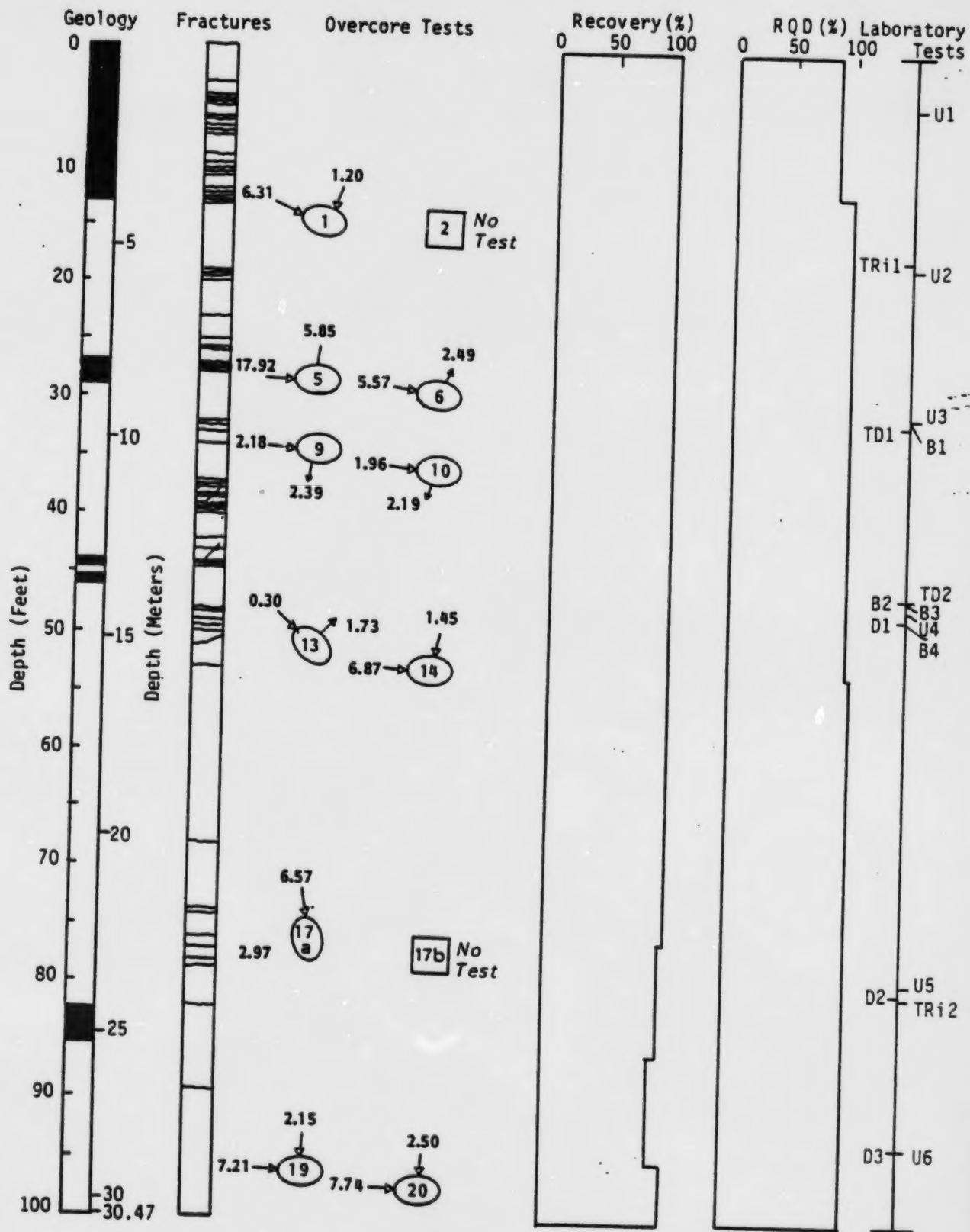


FIGURE 6
BOREHOLE 4 (BH4)

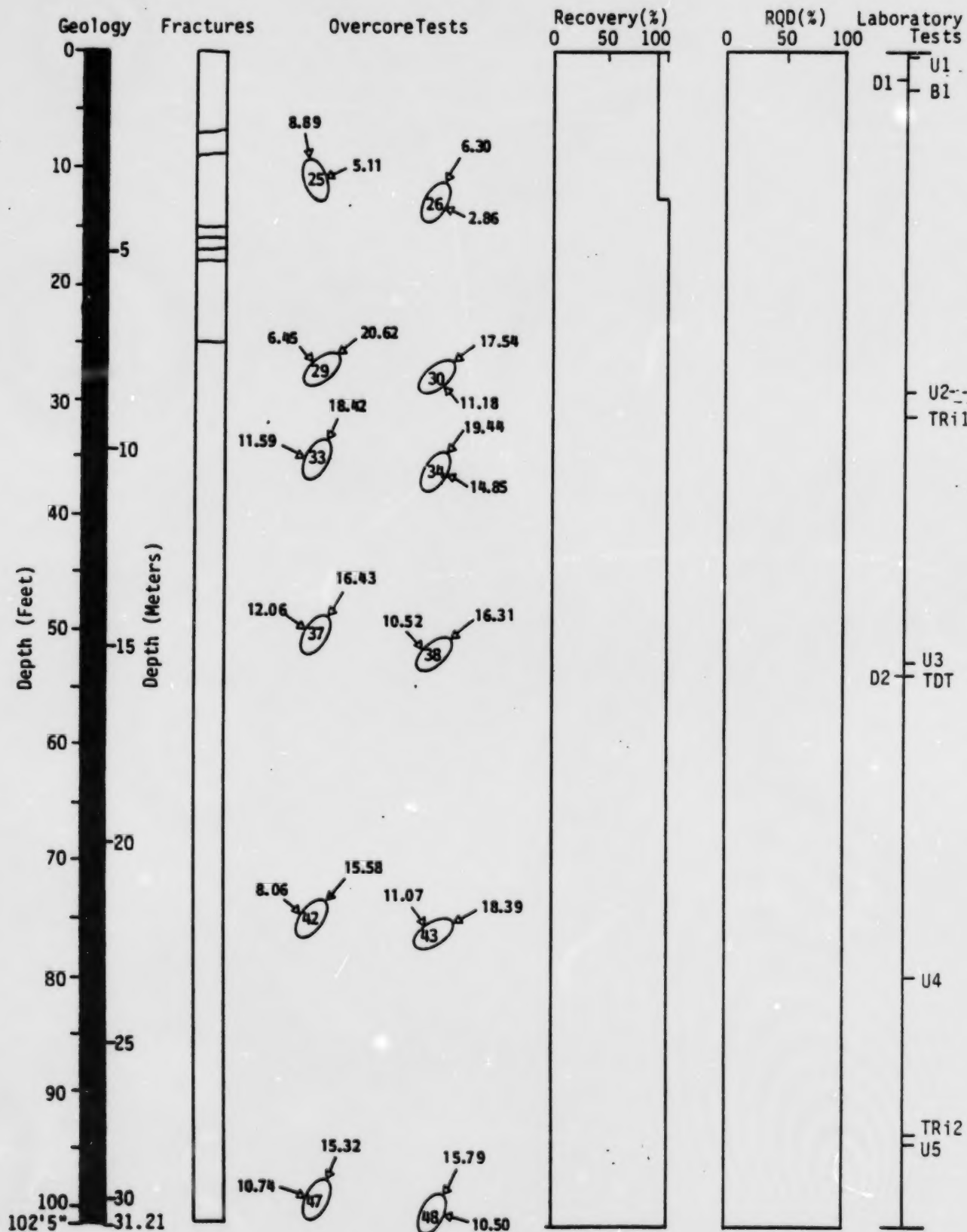


FIGURE 7
BOREHOLE 5 (BH5)

169328 RD

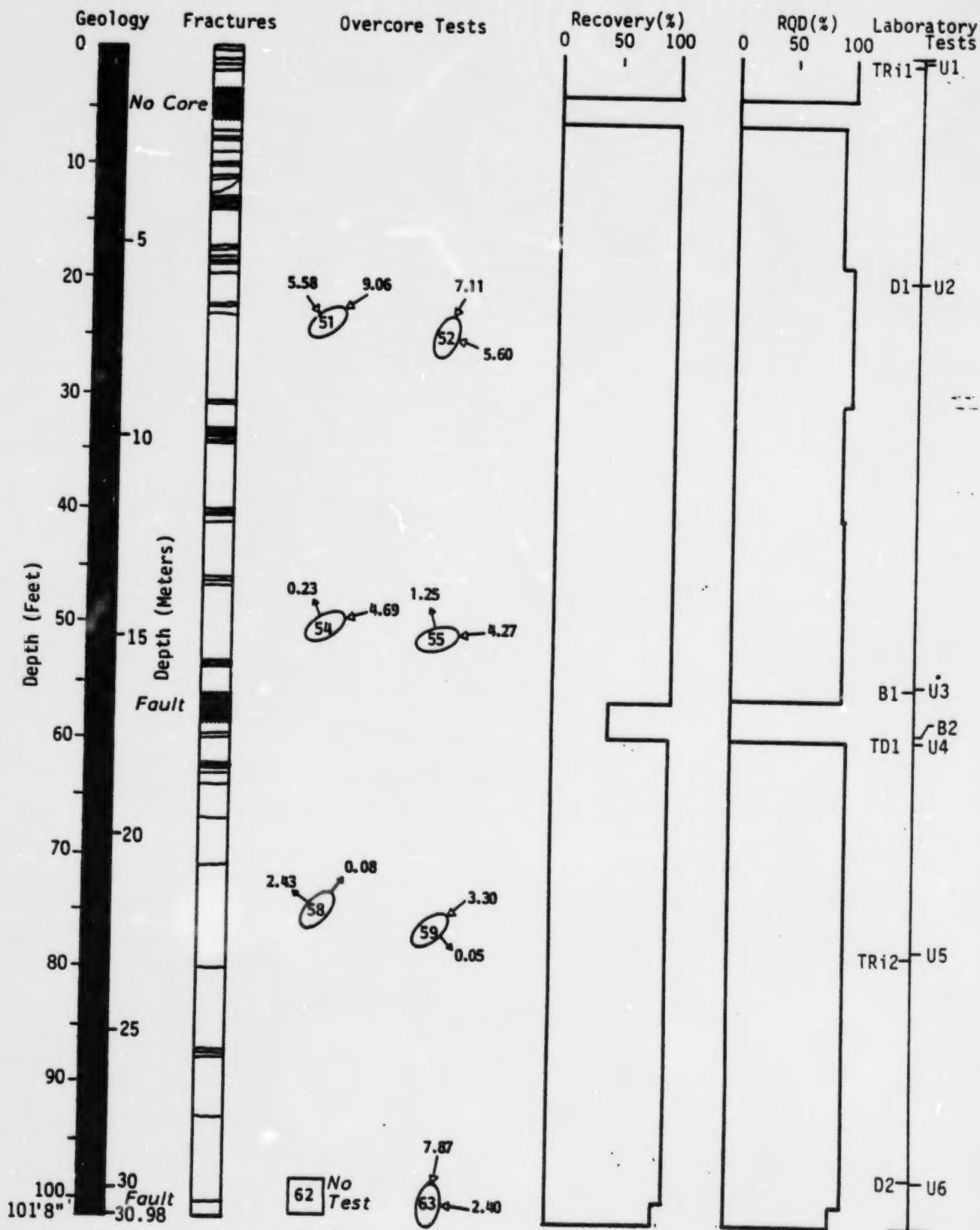


FIGURE 8
BOREHOLE 6 (BH6)

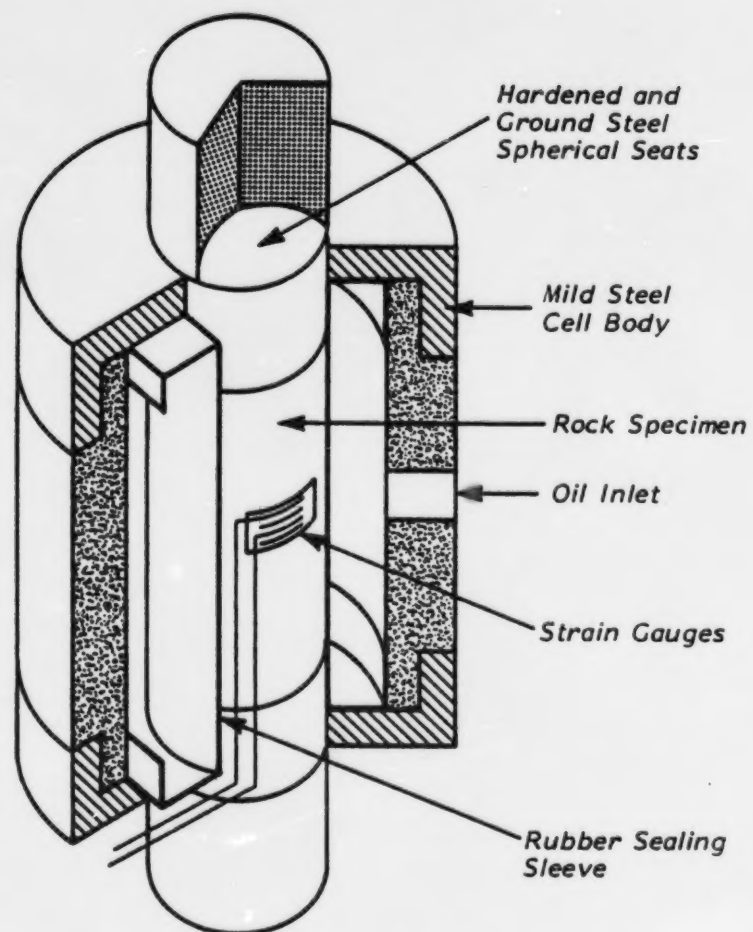


FIGURE 9
TRIAXIAL LOADING CHAMBER WITH
STRAIN GAGE INSTRUMENTATION

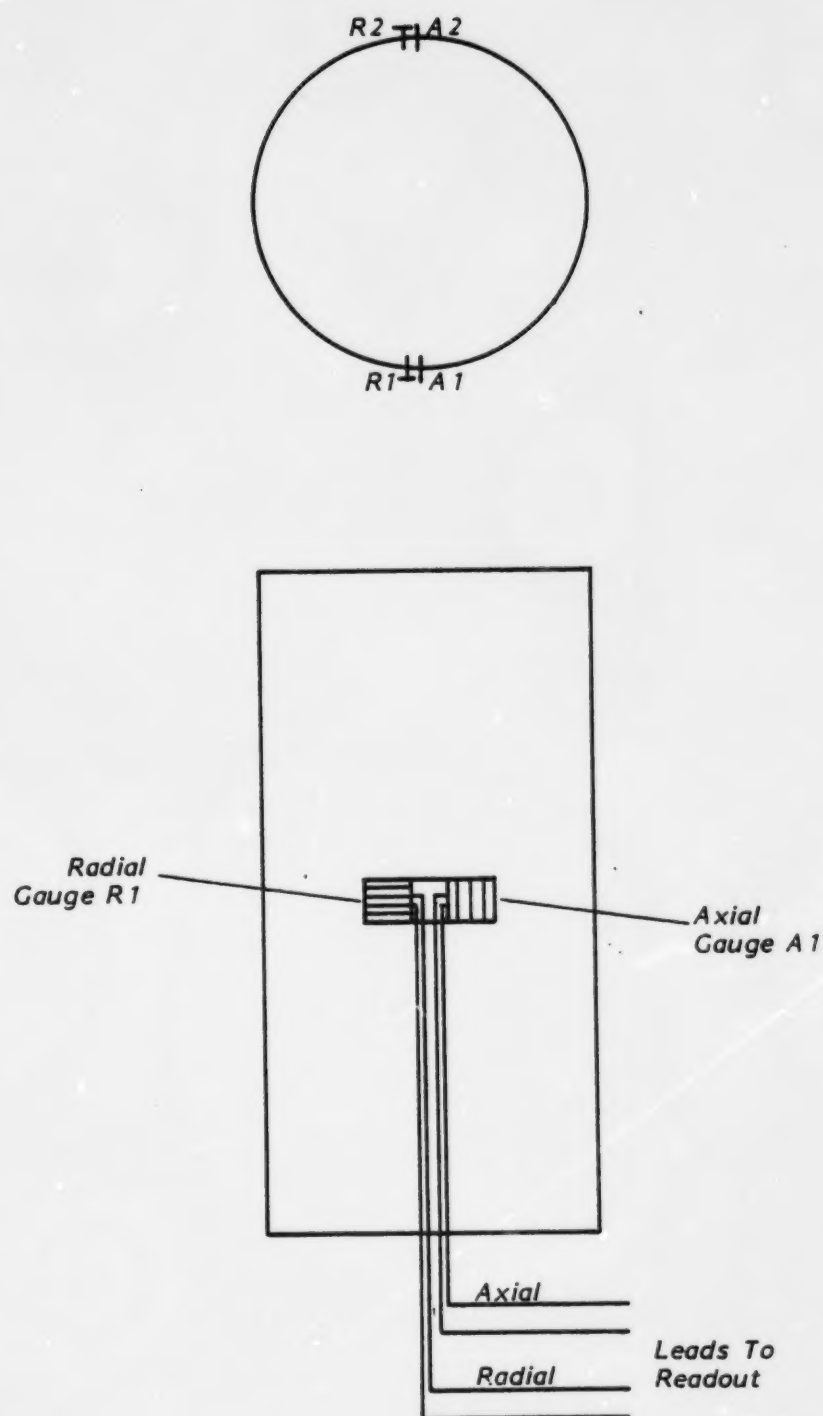


FIGURE 10
STRAIN GAUGE LOCATIONS FOR TRIAXIAL TESTS
DIORITE AND GRANODIORITE SPECIMENS

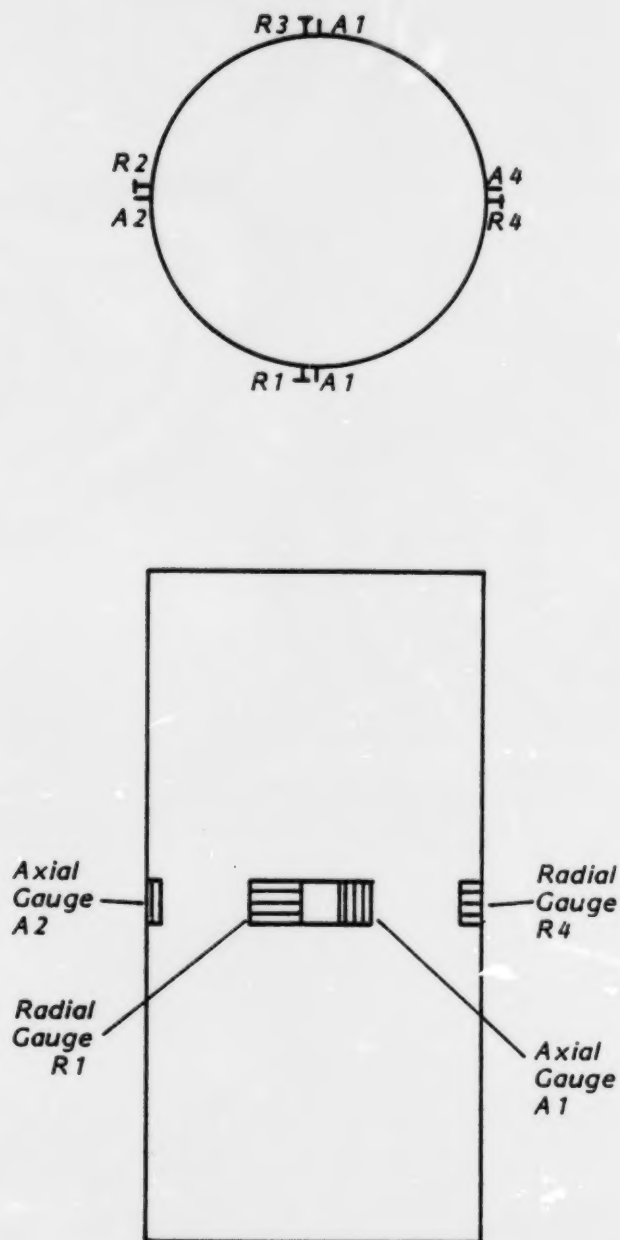


FIGURE 11
STRAIN GAUGE LOCATIONS FOR TRIAXIAL TESTS
GRANITE SPECIMENS

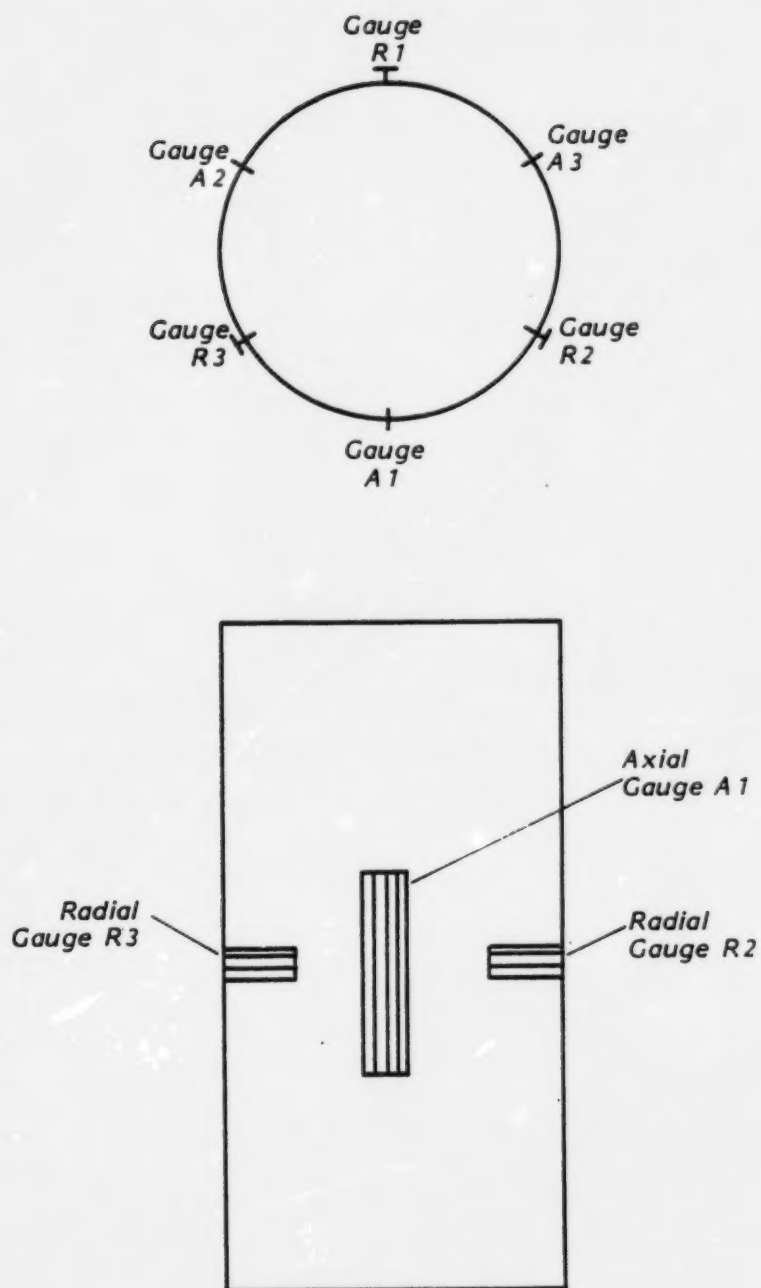


FIGURE 12
STRAIN GAUGE LOCATIONS FOR DIRECT TENSILE TESTS

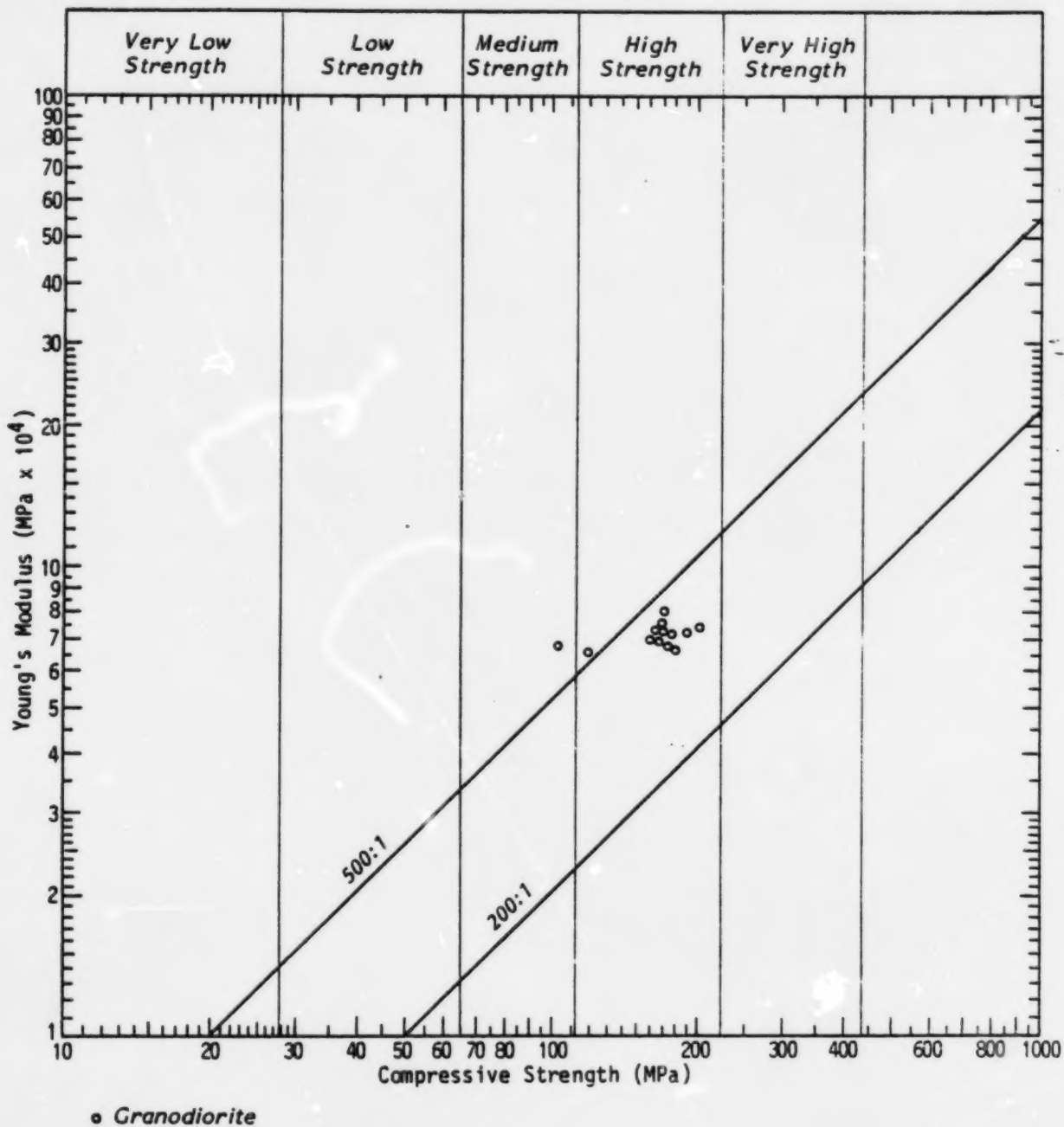


FIGURE 13
ENGINEERING CLASSIFICATION FOR INTACT ROCK
(AFTER DEERE AND MILLER, 1966)

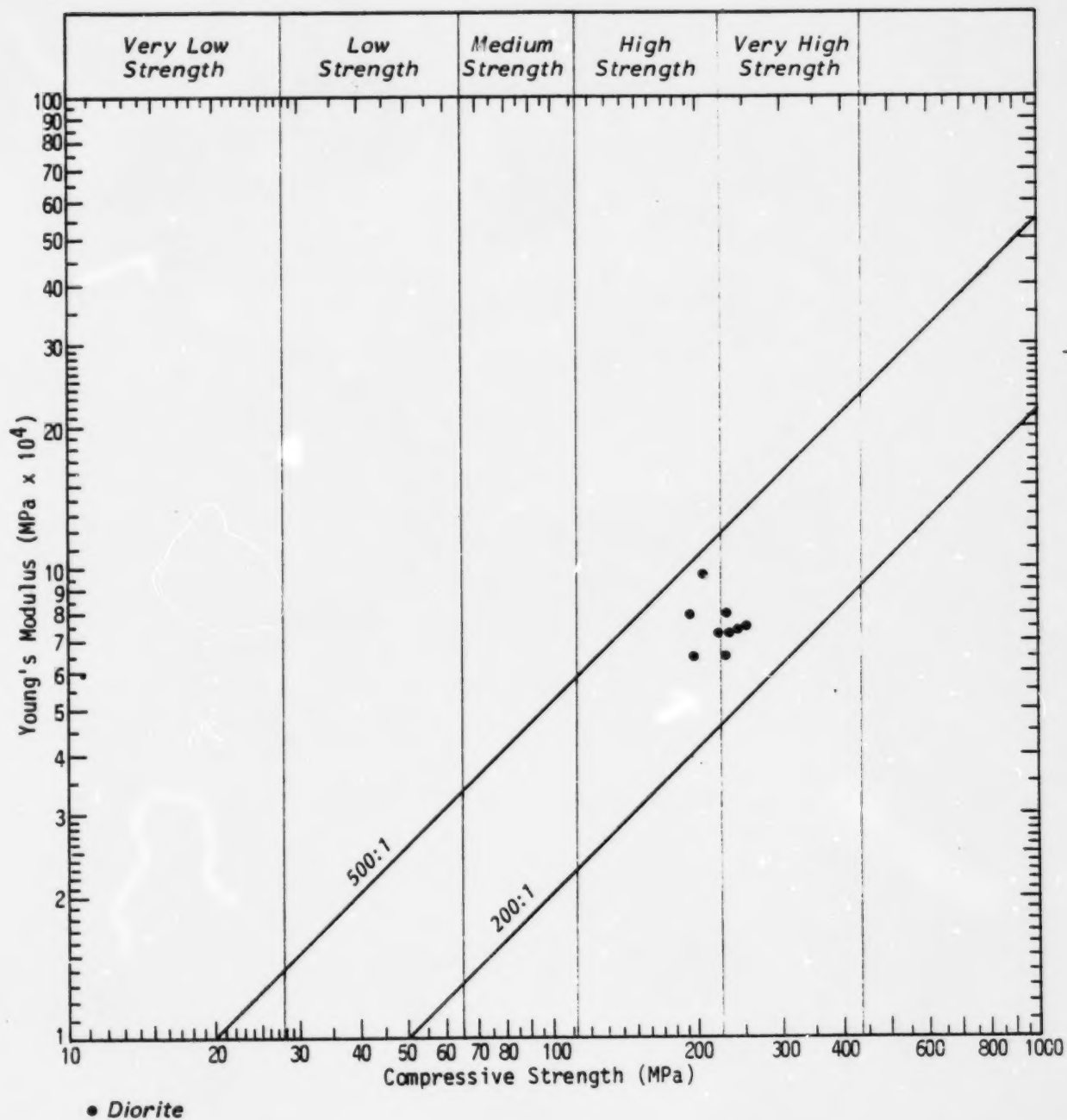


FIGURE 14
ENGINEERING CLASSIFICATION FOR INTACT ROCK
(AFTER DEERE AND MILLER, 1966)

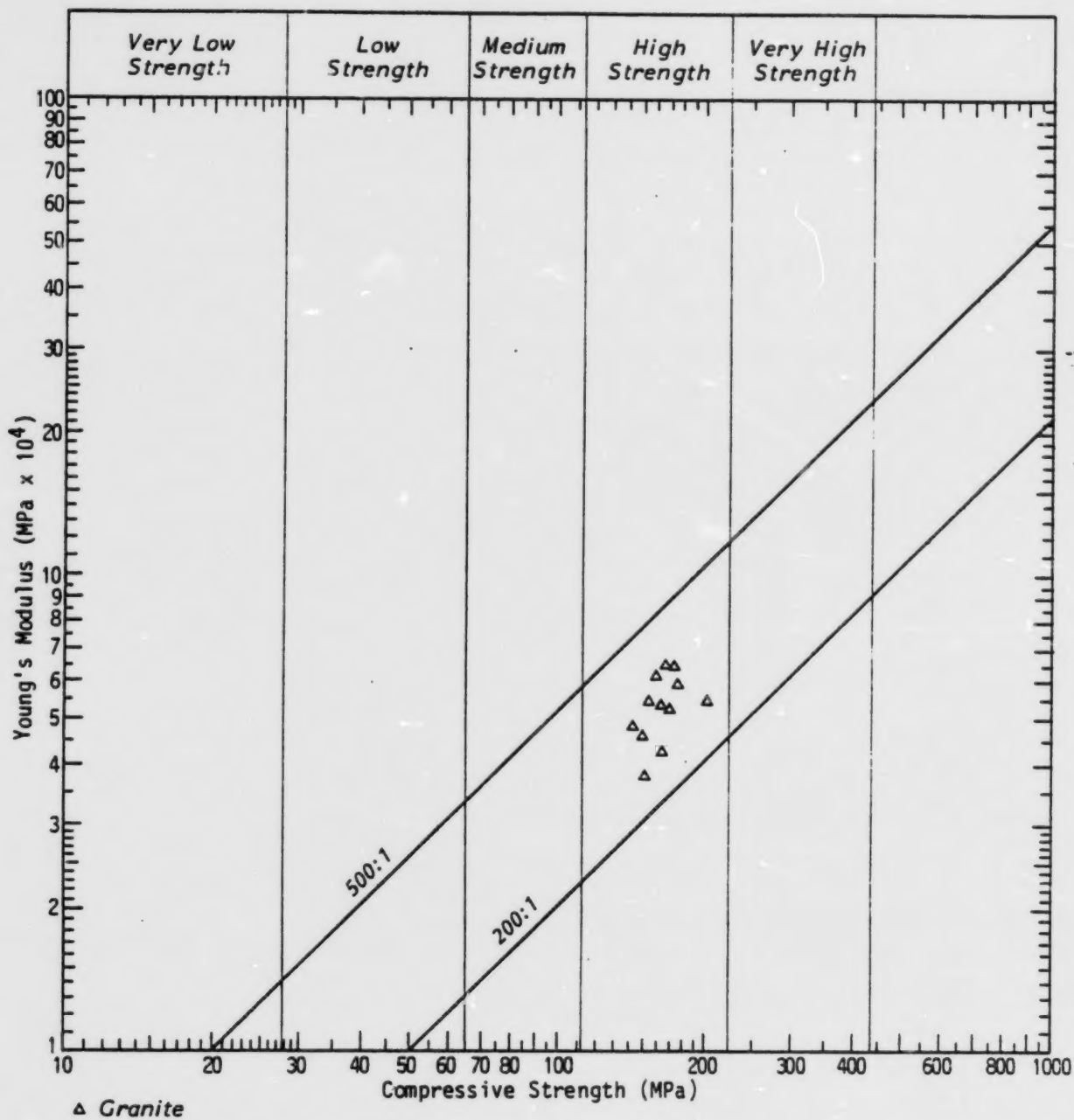


FIGURE 15
ENGINEERING CLASSIFICATION FOR INTACT ROCK
(AFTER DEERE AND MILLER, 1966)

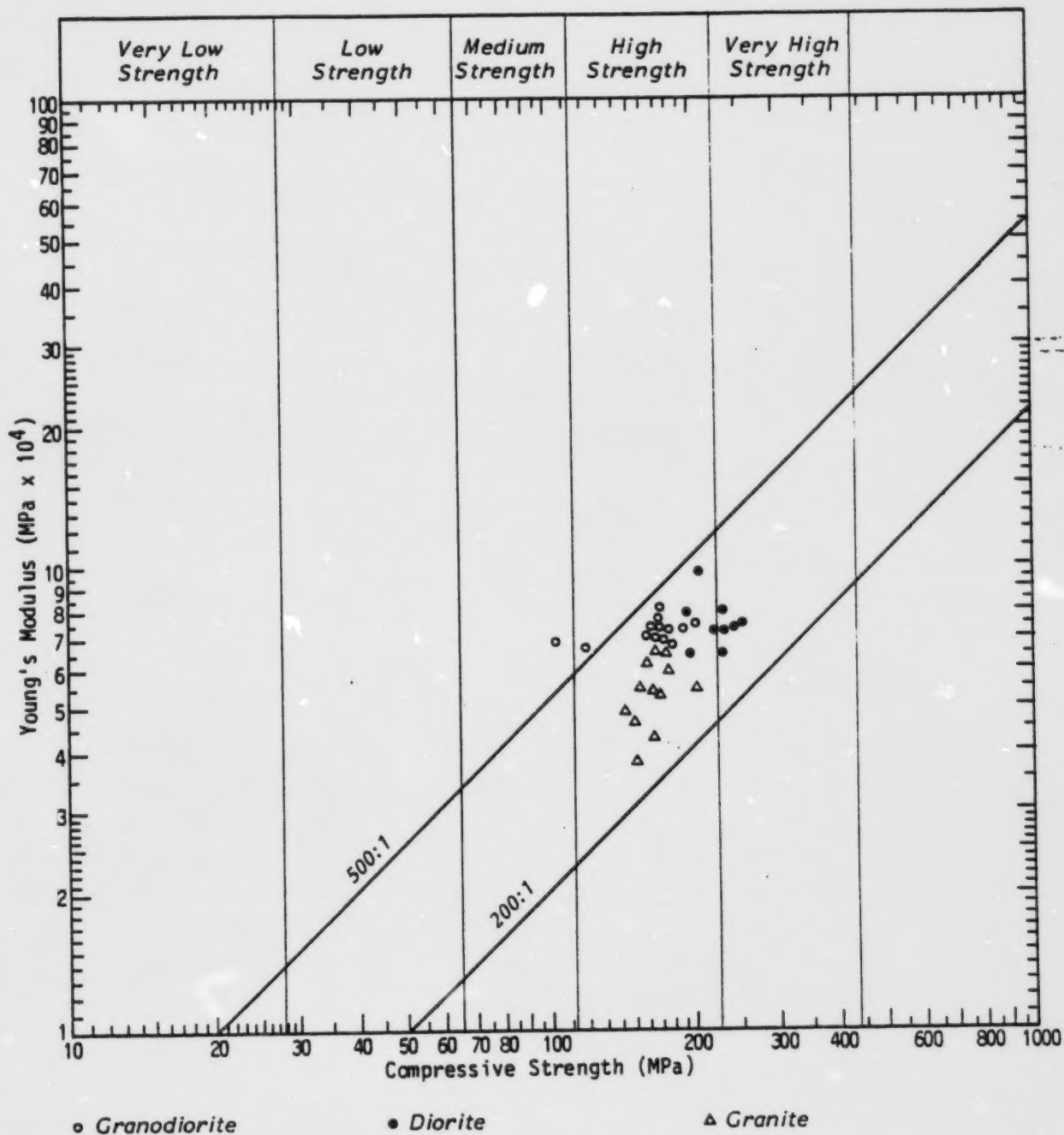


FIGURE 16

ENGINEERING CLASSIFICATION FOR INTACT ROCK
(AFTER DEERE AND MILLER, 1966)

APPENDIX 1
STRESS-STRAIN CURVES
UNCONFINED COMPRESSION TESTS

Stress-Strain Curves

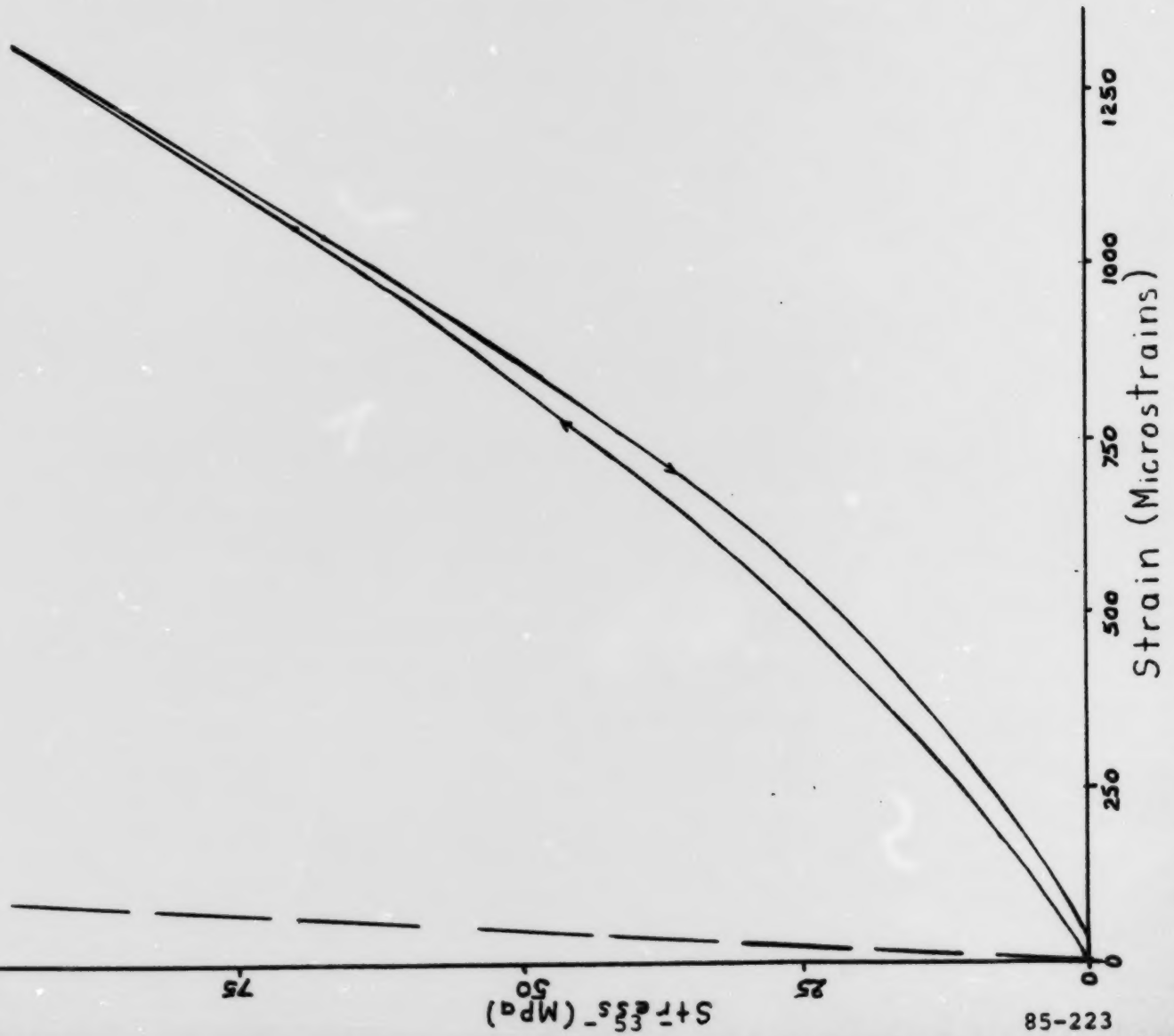
P-3708- U₁

BH-1

Depth-378 M.

— Radial

— Axial



Stress-Strain Curves

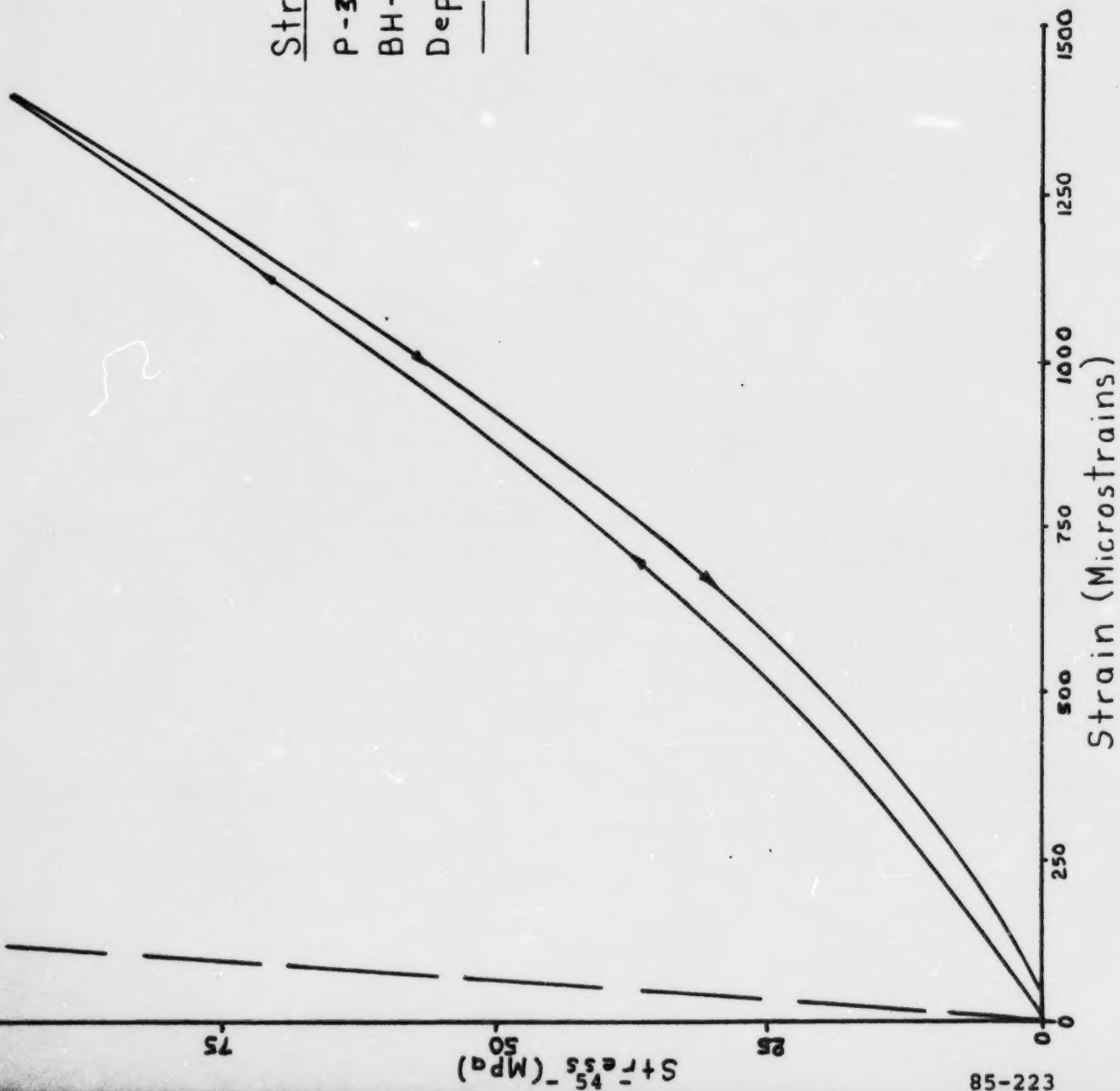
P-3708-U2

BH-1

Depth - 12.86 M.

— Radial

— Axial



Stress-Strain Curves

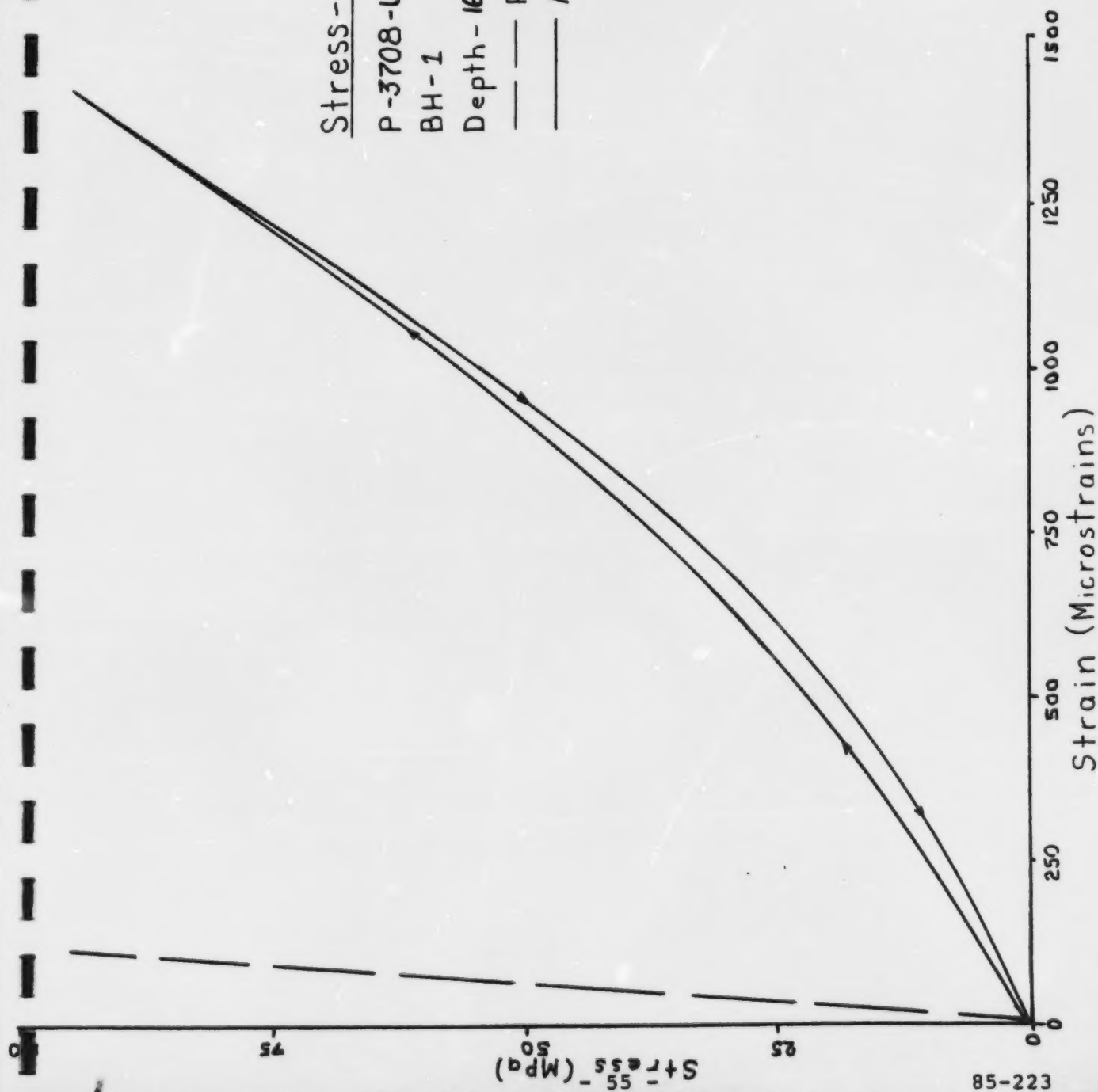
P-3708-U3

BH-1

Depth - 16.60 M.

— Radial

— Axial



Stress-Strain Curves

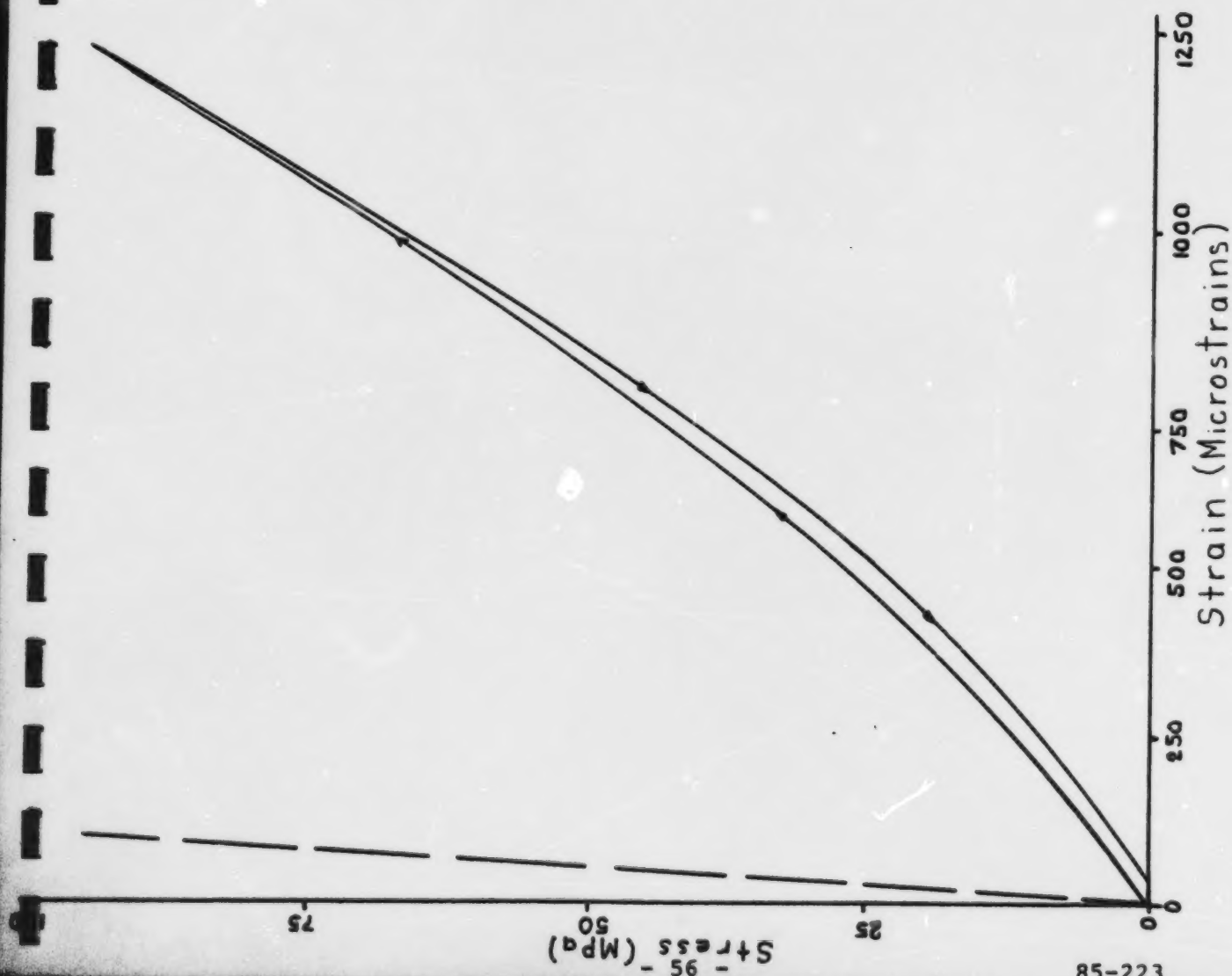
P-3708-U*

BH-1

Depth-22.22 M.

— Radial

— Axial



Stress-Strain Curves

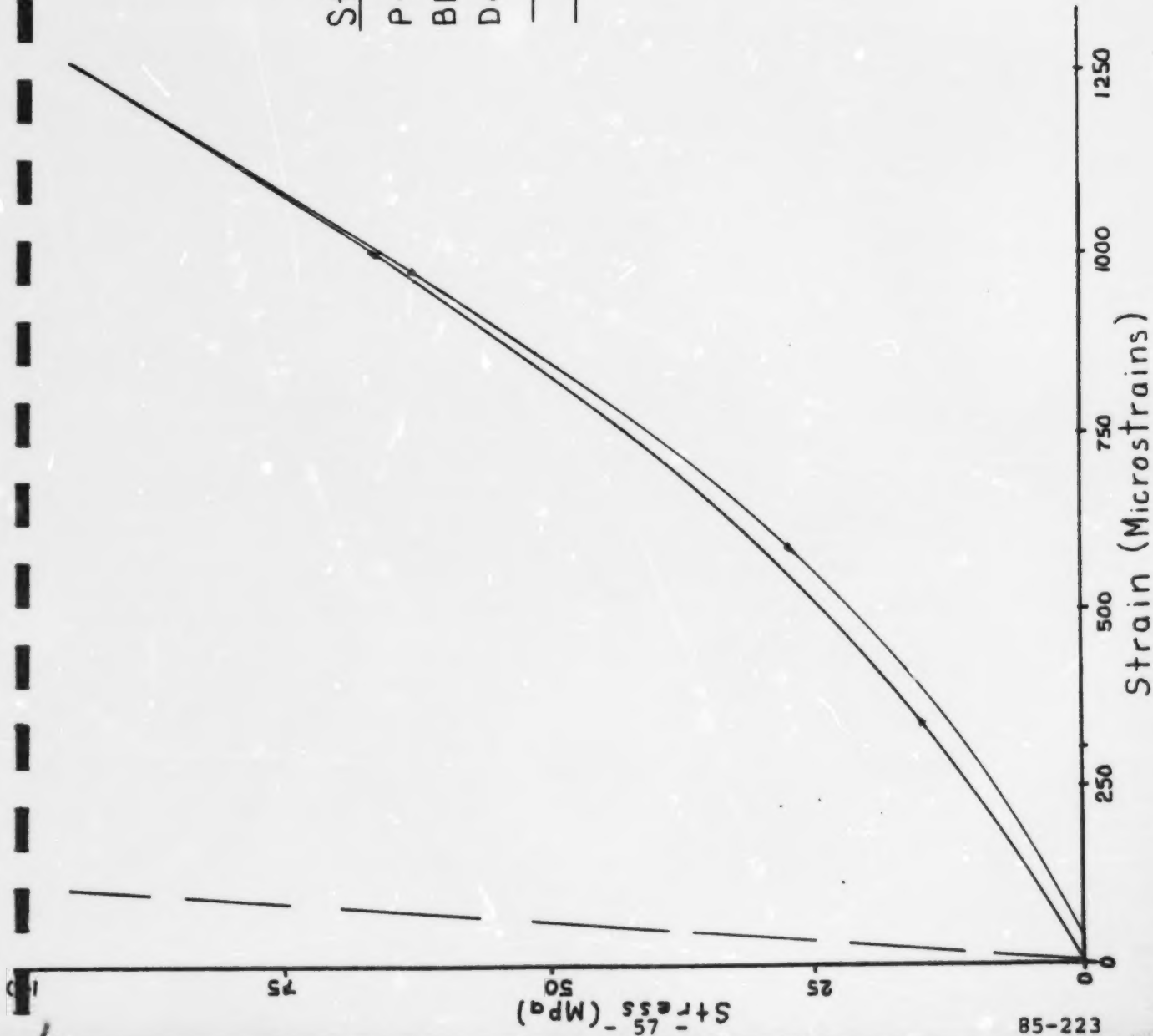
P-3708-U5

BH-1

Depth-29.38 M.

--- Radial

— Axial



Stress-Strain Curves

P-3709U₁

BH-2

Depth-2.38 M.

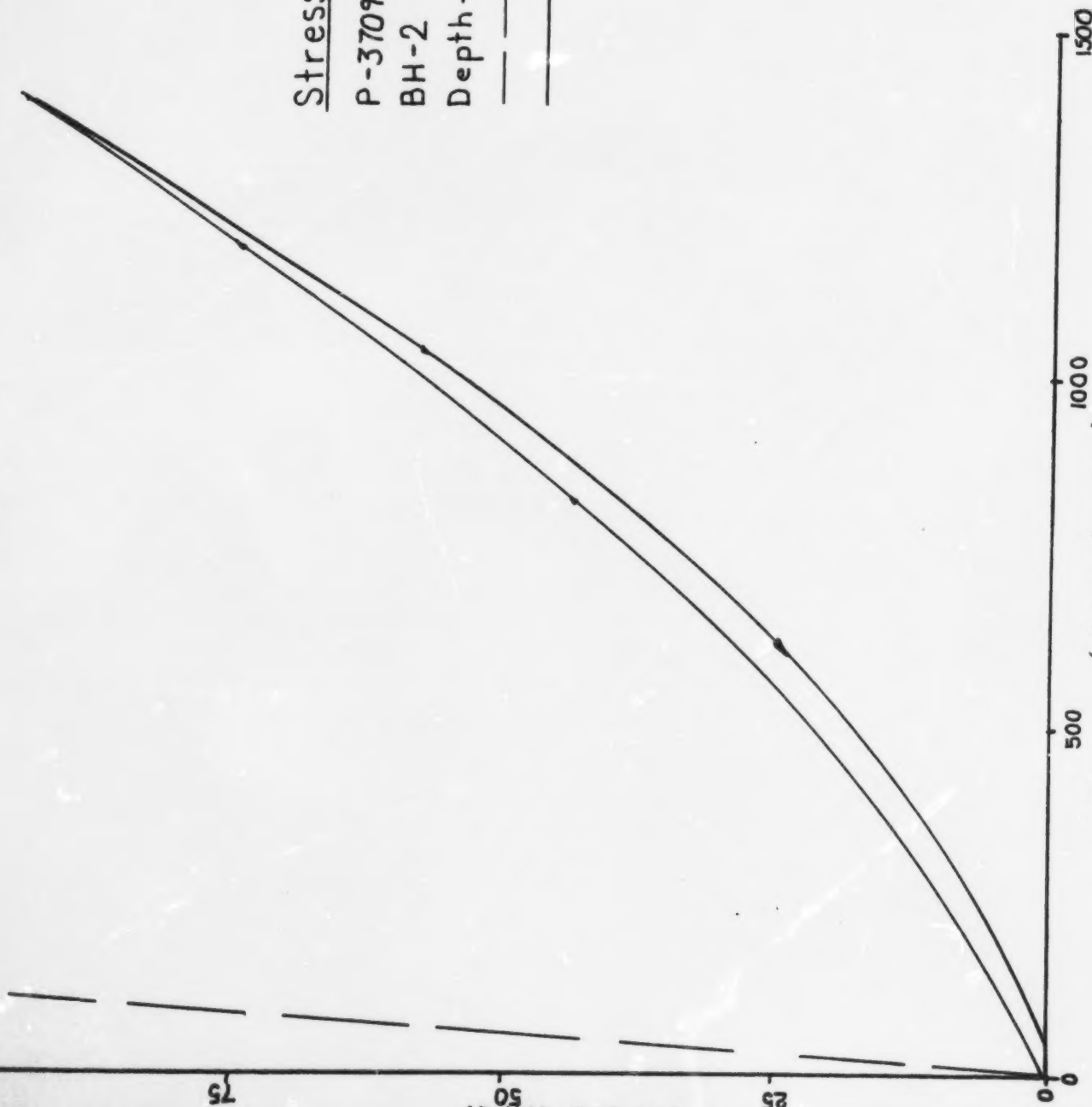
— Radial

— Axial

85-223

Stress (MPa)

Strain (Microstrains)



Stress-Strain Curves

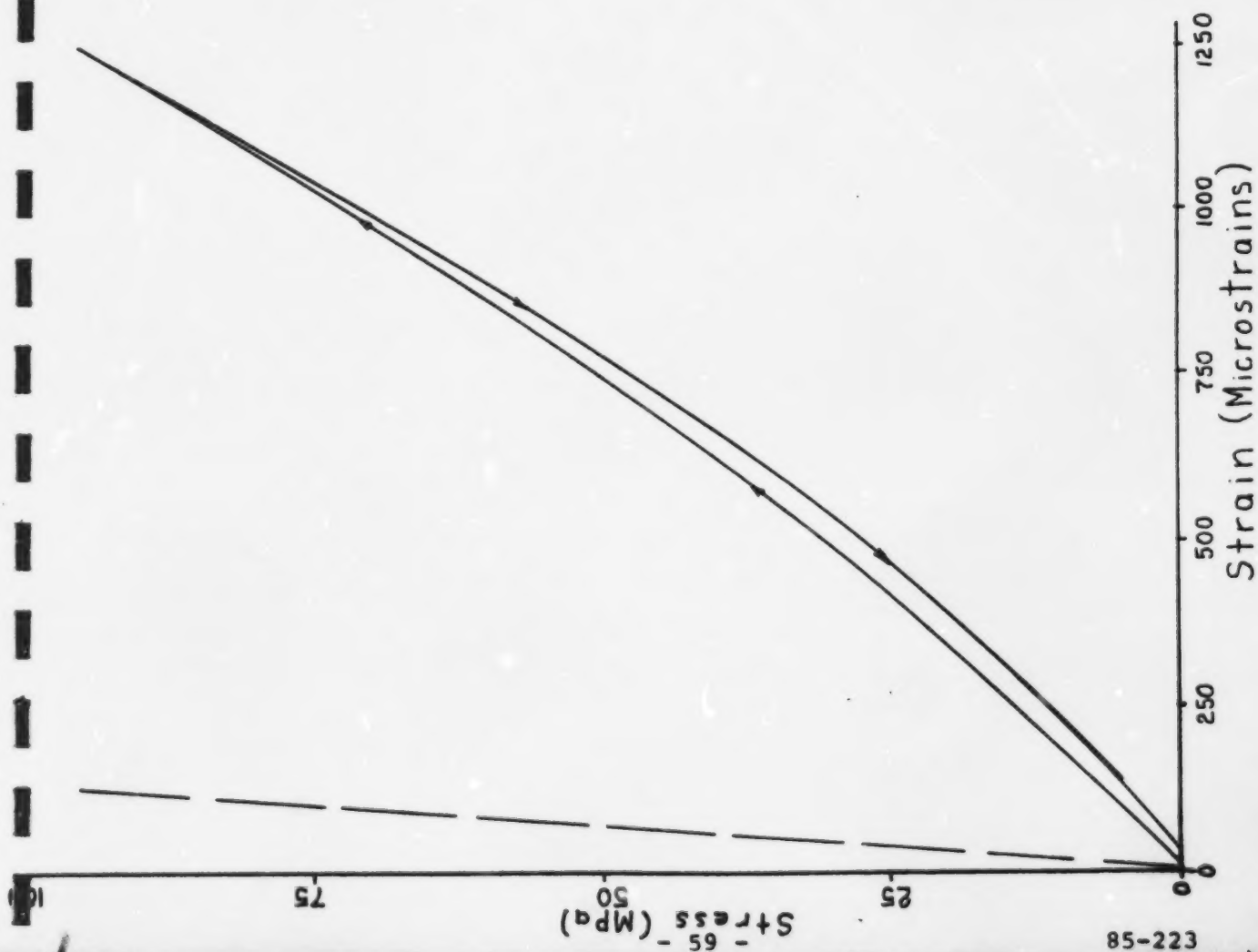
P-3709-U2

BH-2

Depth - 8.18M

--- Radial

— Axial



Stress-Strain Curves

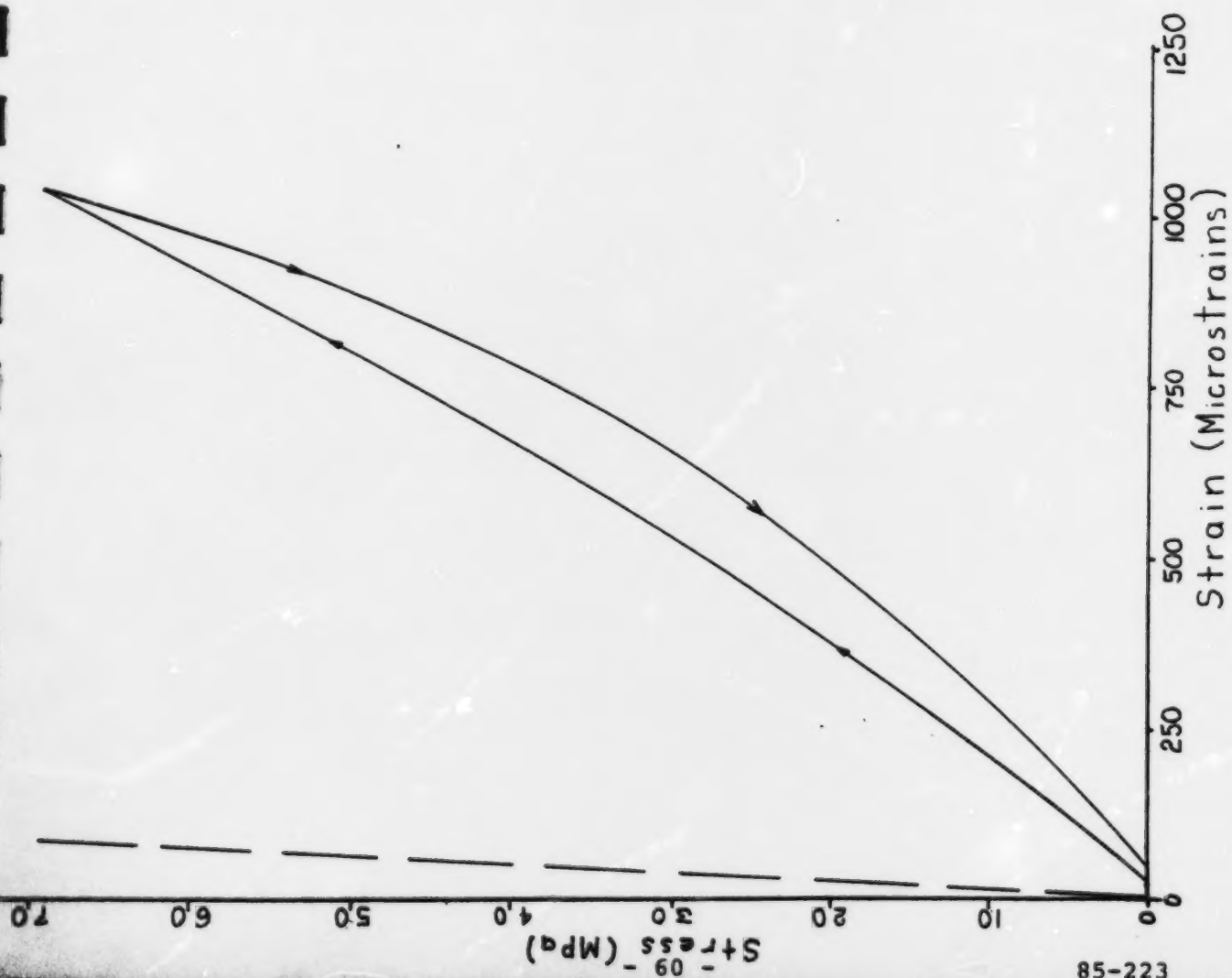
P-3709 U₃

BH-2

Depth - 11.11 M

— Radial

— Axial



Stress-Strain Curves

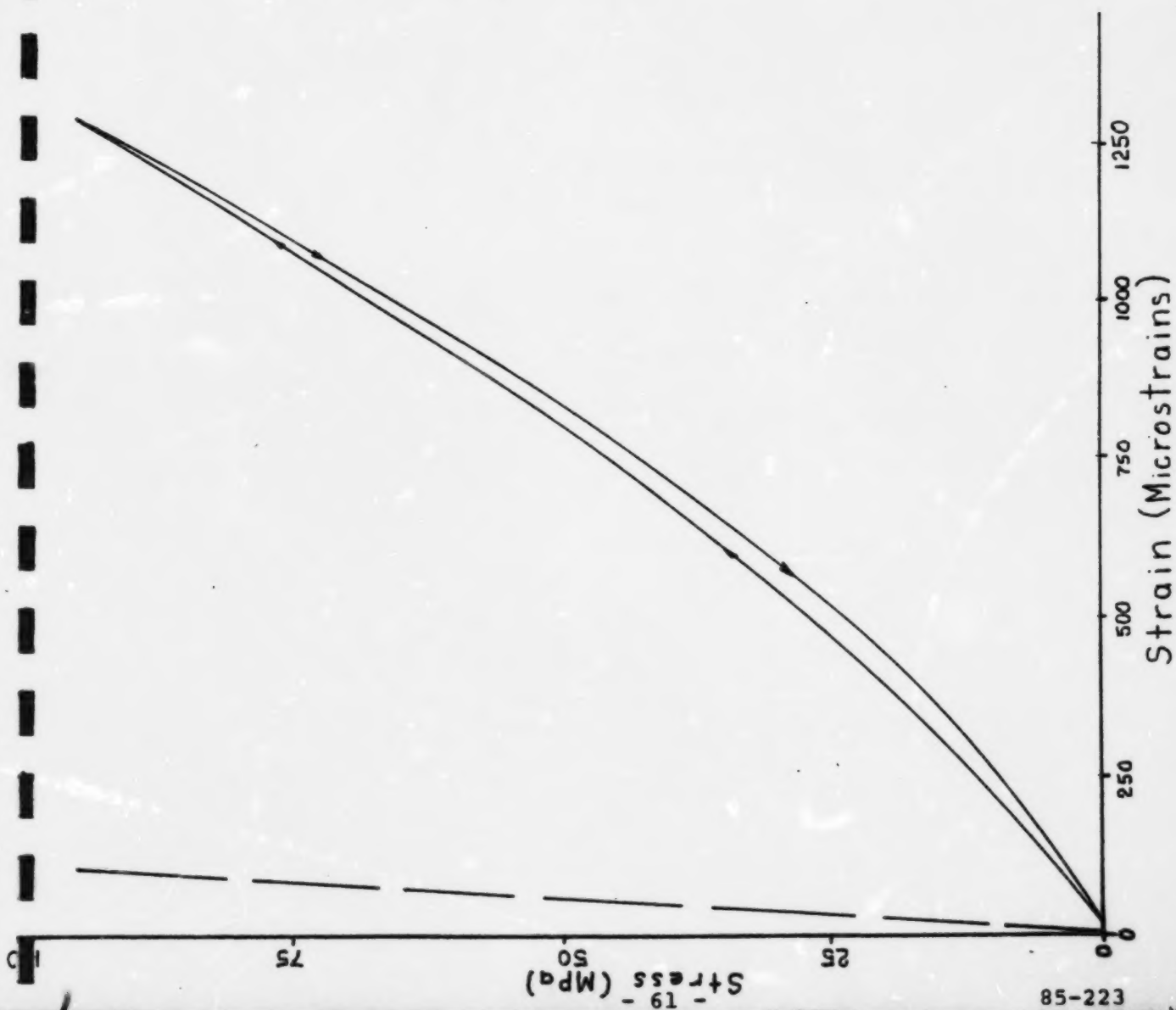
P-3709-U4

BH-2

Depth - 17.28 M.

— Radial

— Axial



Stress-Strain Curves

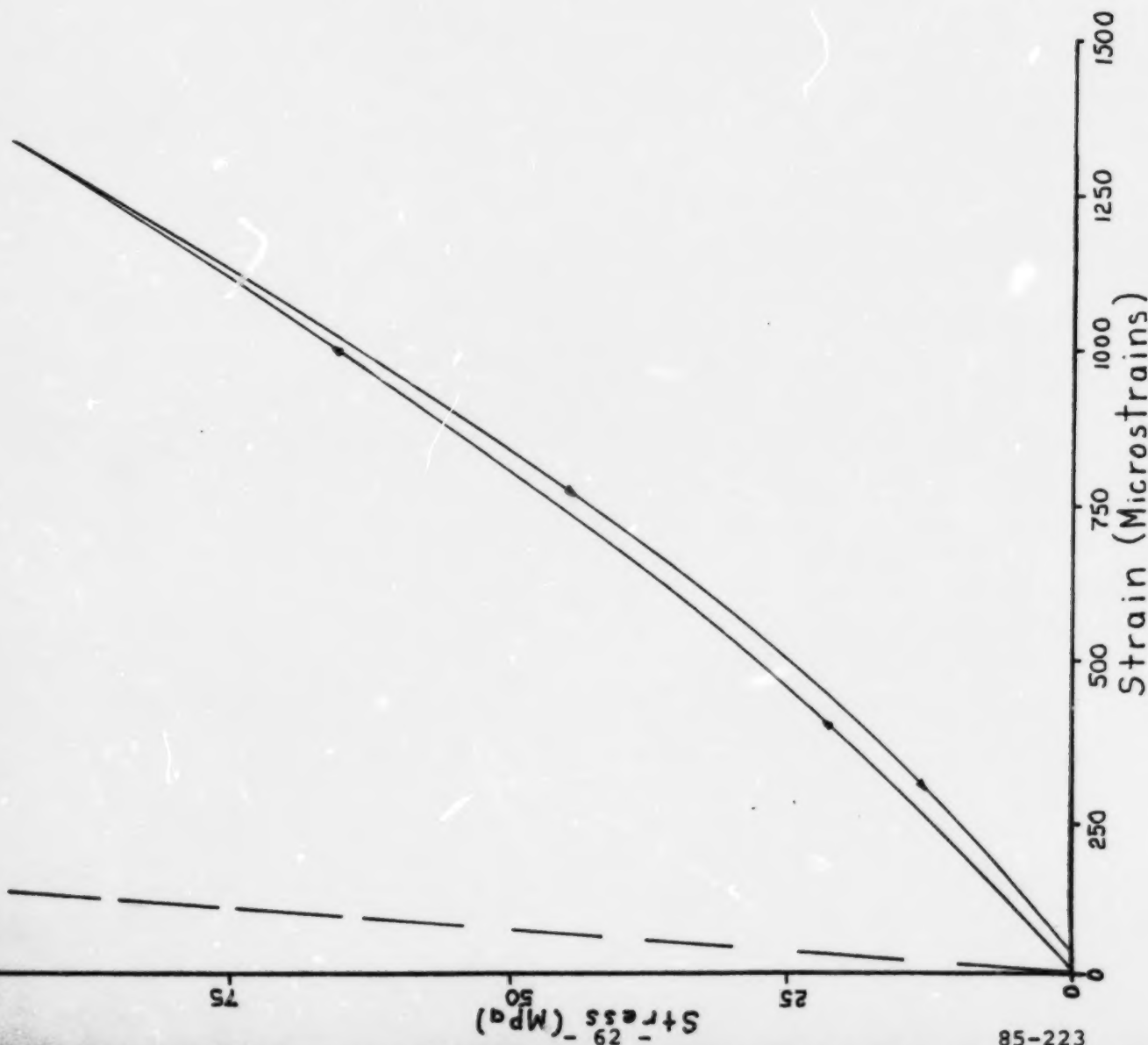
P-3709-U5

BH-2

Depth-25.38 M.

— Radial

— Axial



Stress-Strain Curves

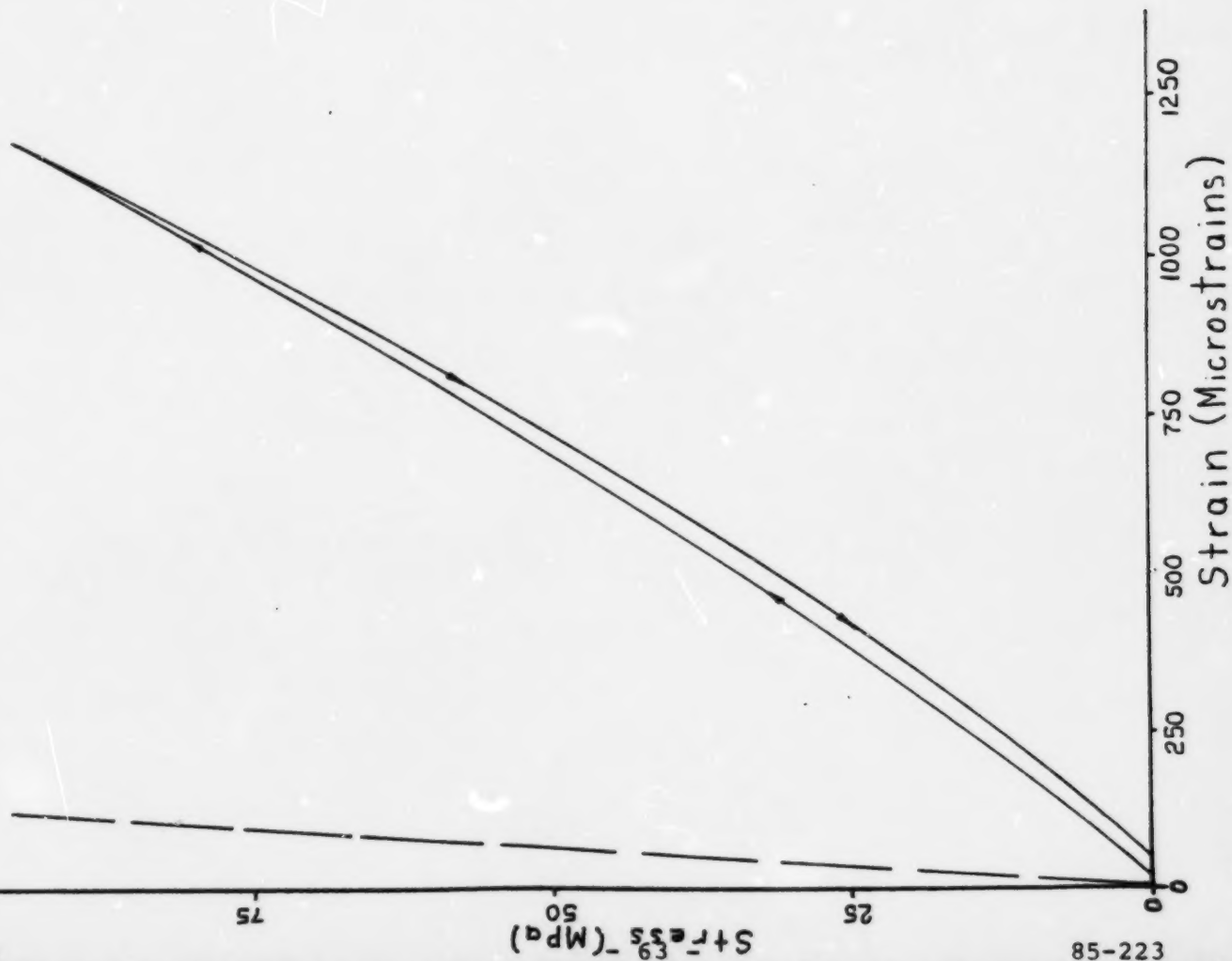
P-3709-U6

BH-2

Depth - 29.42 M.

— Radial

— Axial



Stress-Strain Curves

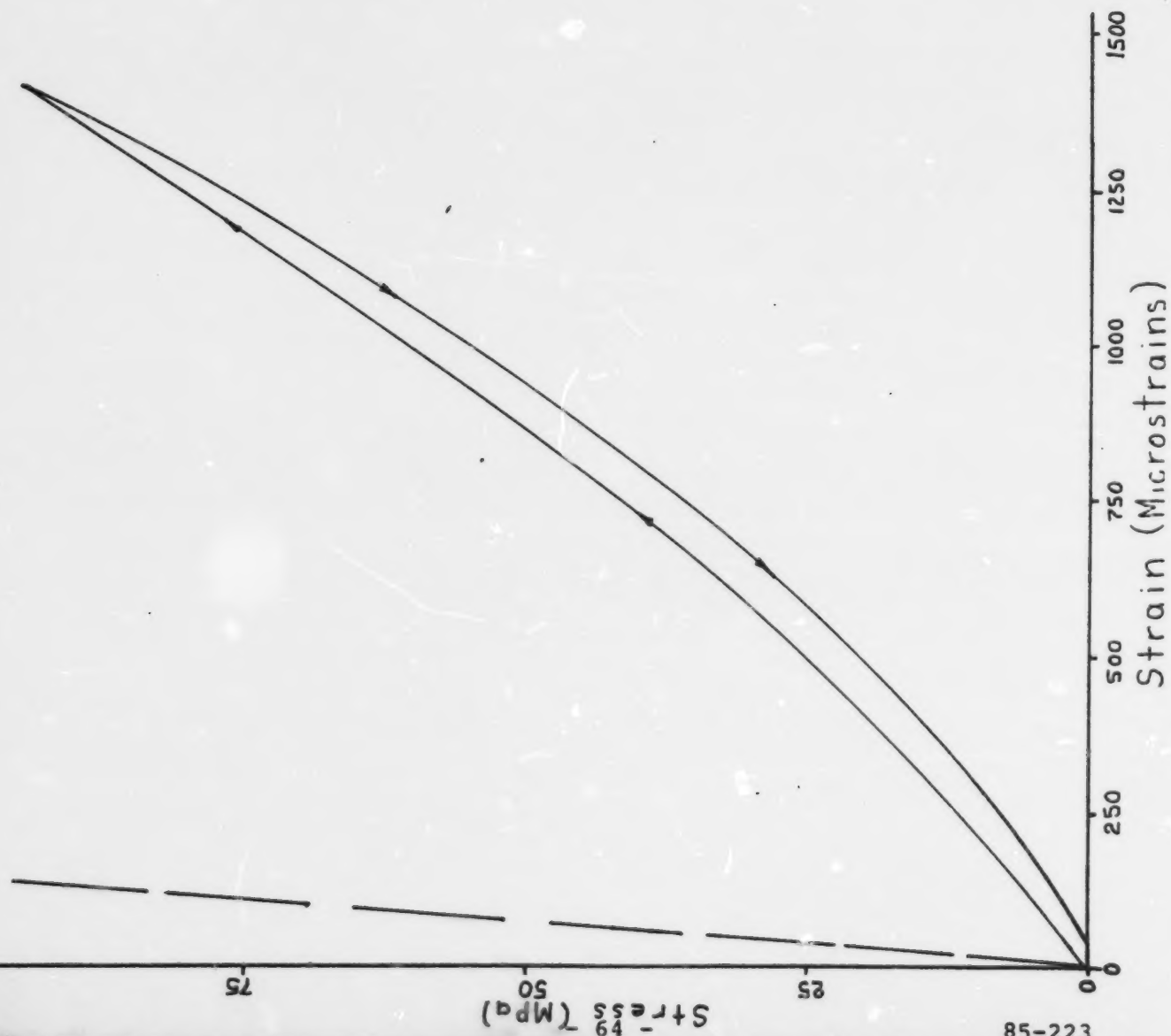
P-3710-U₁

BH-3

Depth - 1.75 M.

— Radial

— Axial



Stress-Strain Curves

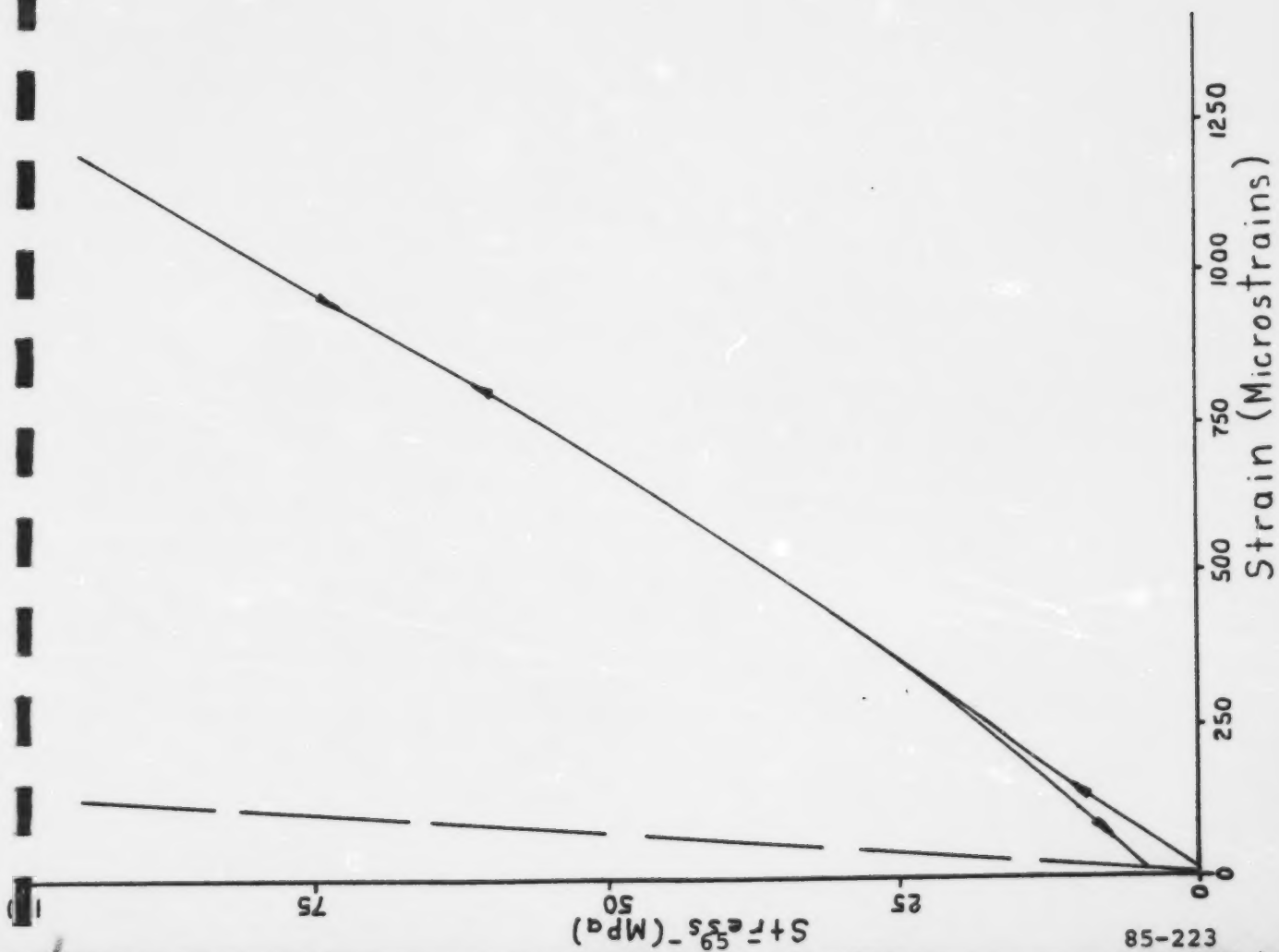
P-3710-U2

BH-3

Depth-2.23 M.

— Radial

— Axial



Stress-Strain Curves

P-3710-U3

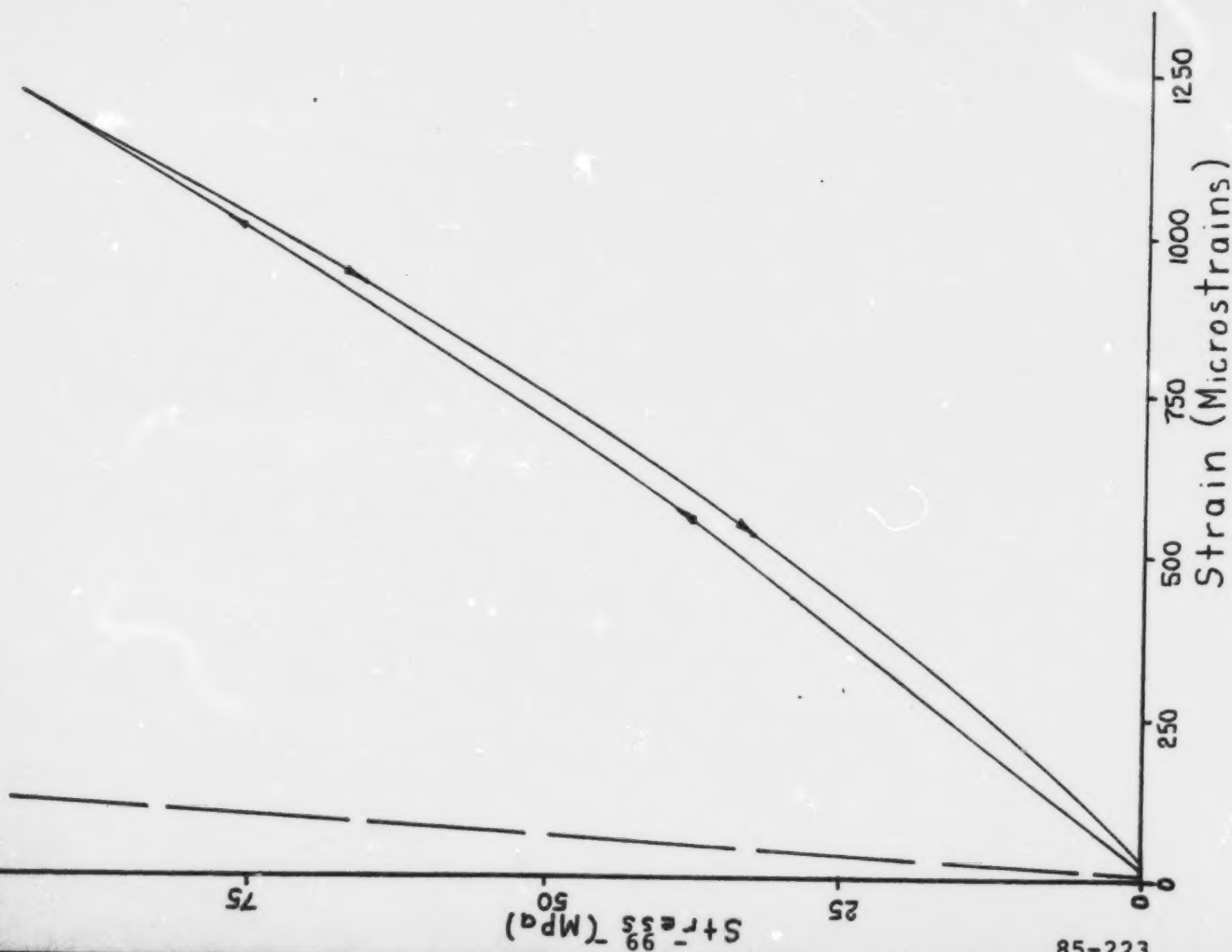
BH-3

Depth-7.27 M.

— Radial

— Axial

85-223



Stress-Strain Curves

P-3710-U4

BH-3

Depth - 16.87 M.

— Radial

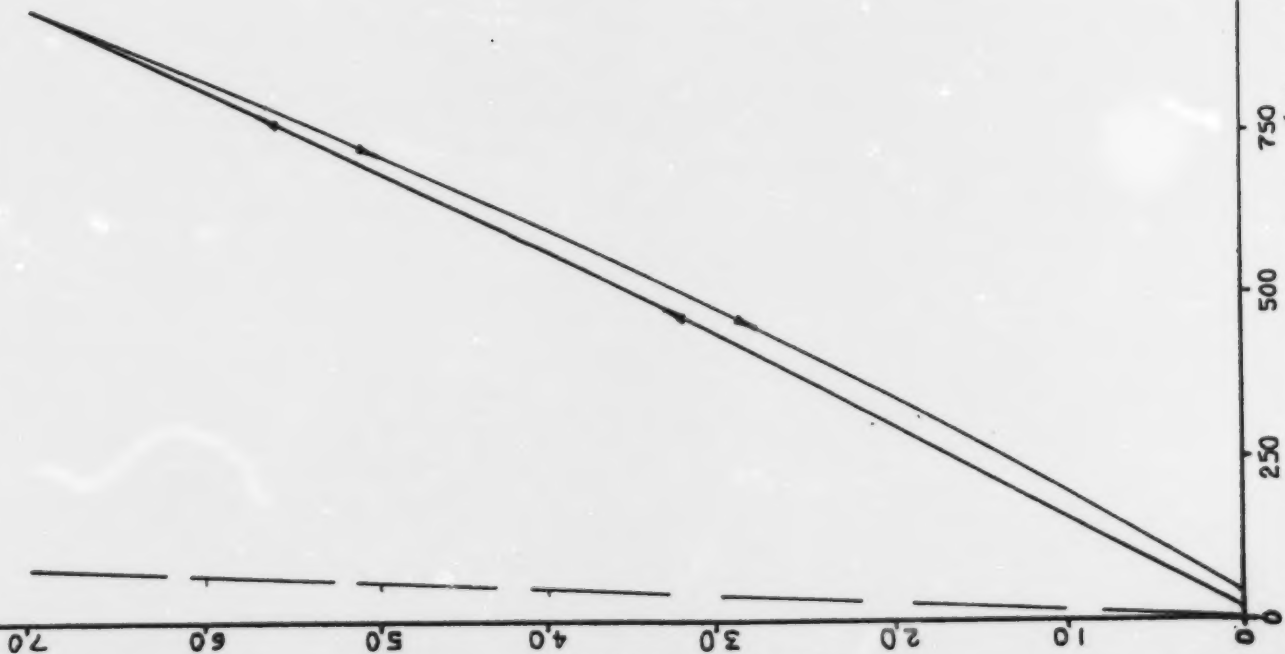
— Axial

85-223

Stress (MPa)

Strain (Microstrains)

250 500 750 1000 1250



Stress-Strain Curves

P-3710-U5

BH-3

Depth-17.66 M.

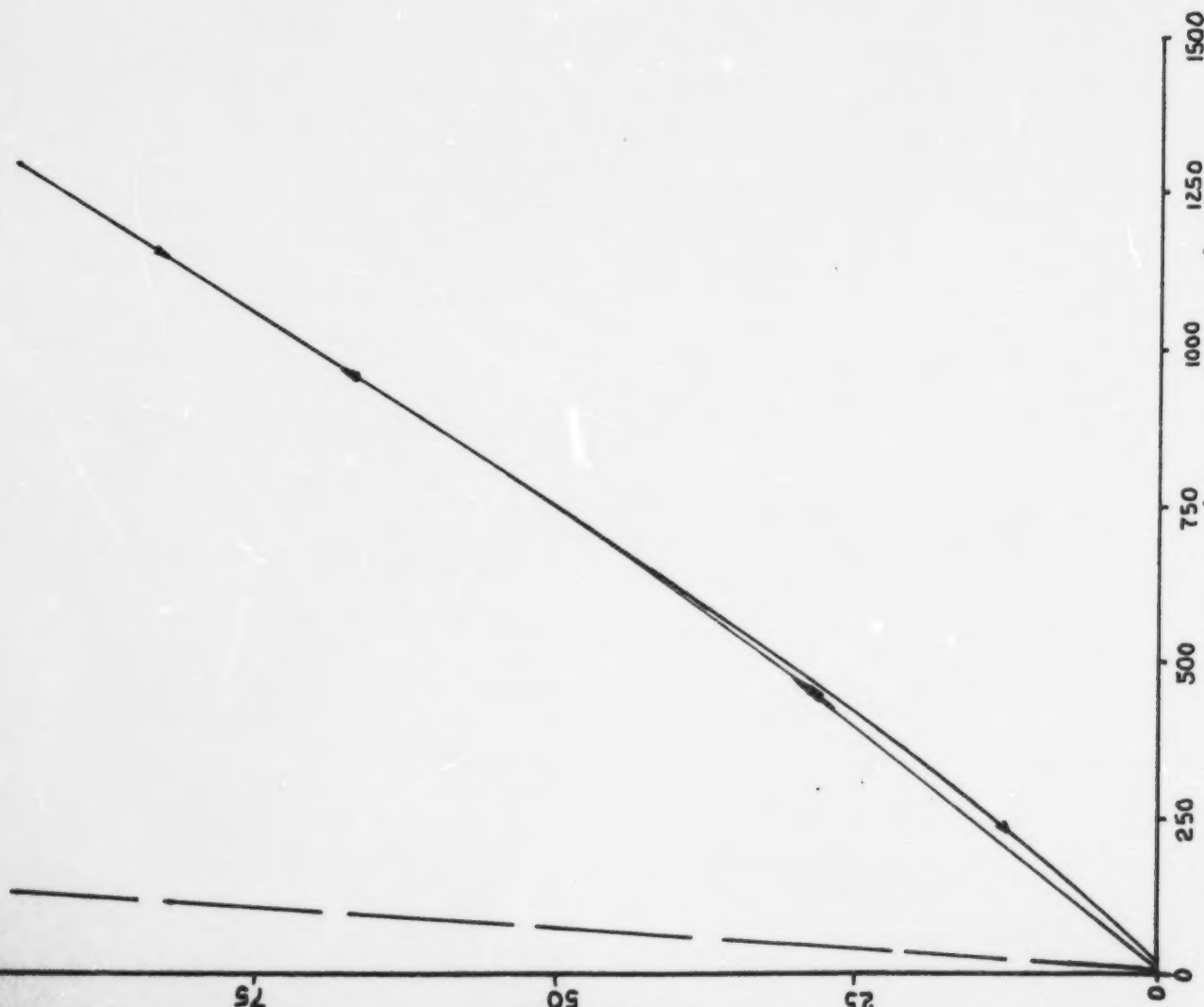
--- Radial

— Axial

85-223

Stress (MPa)

Strain (Microstrains)



Stress-Strain Curves

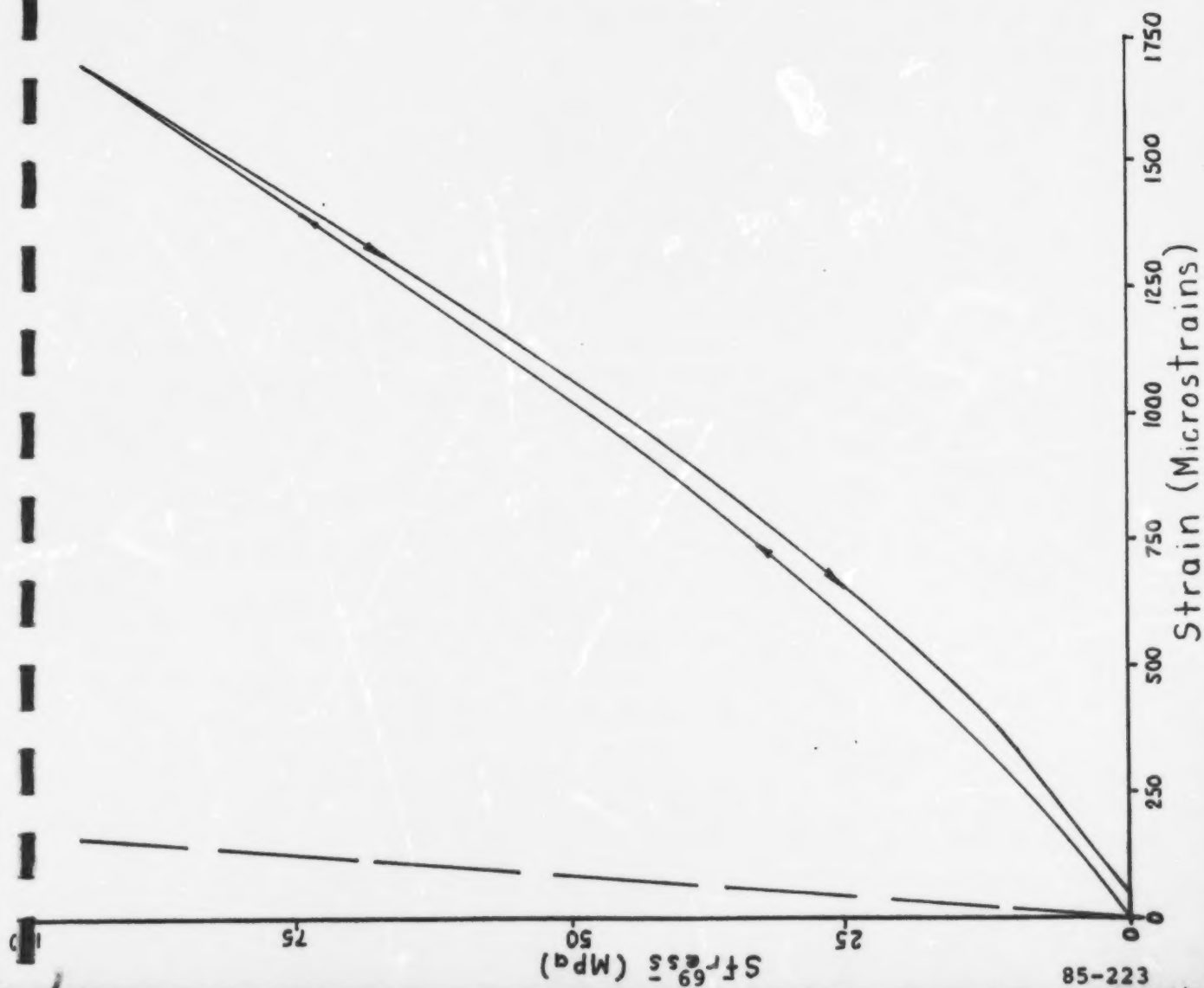
P-3710-U6

BH-3

Depth-29.02 M.

— Radial

— Axial



Stress-Strain Curves

P-3711-U₁

BH-4

Depth-152 M.

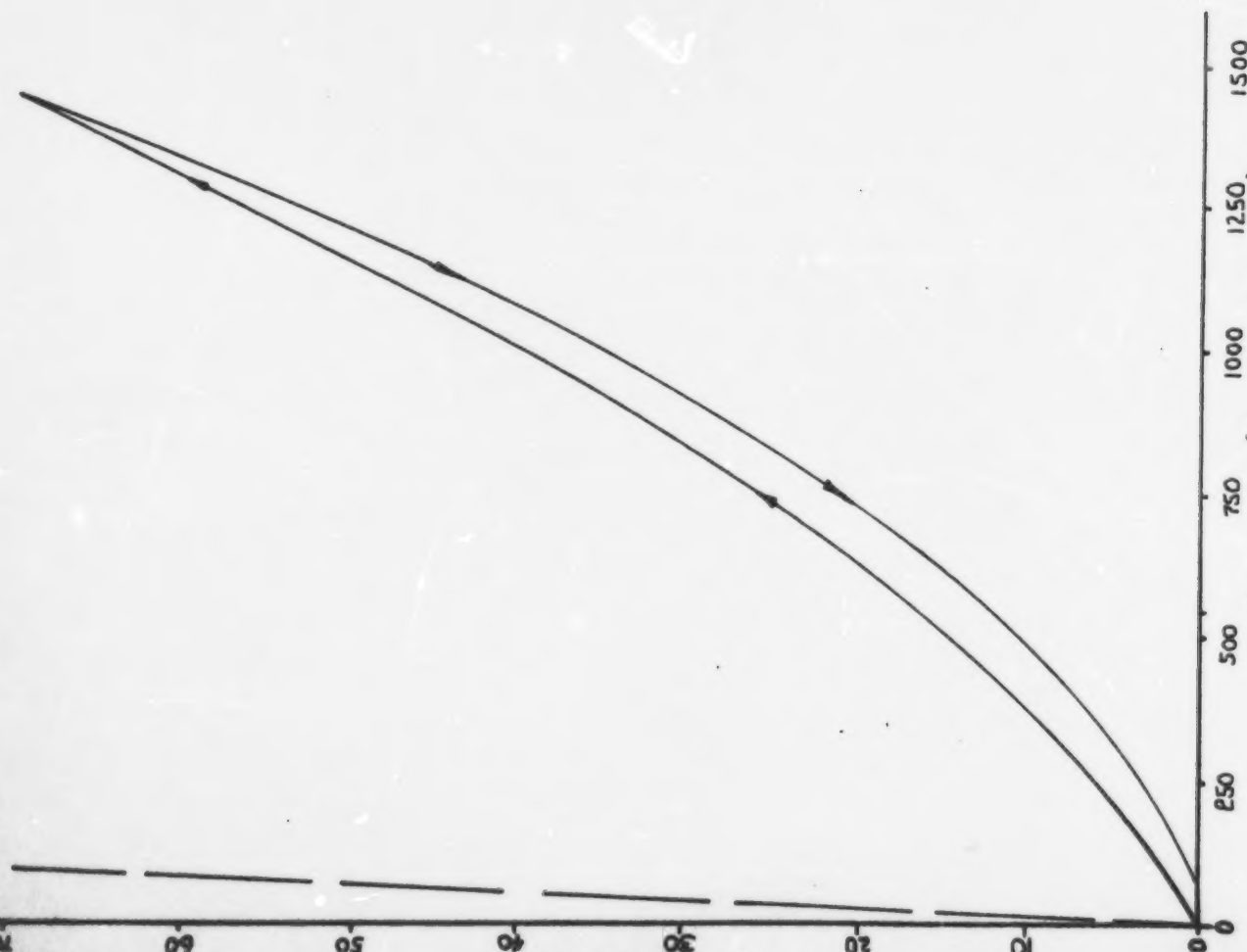
— Radial

— Axial

85-223

Stress (Mpa)

Strain (Microstrains)



Stress-Strain Curves

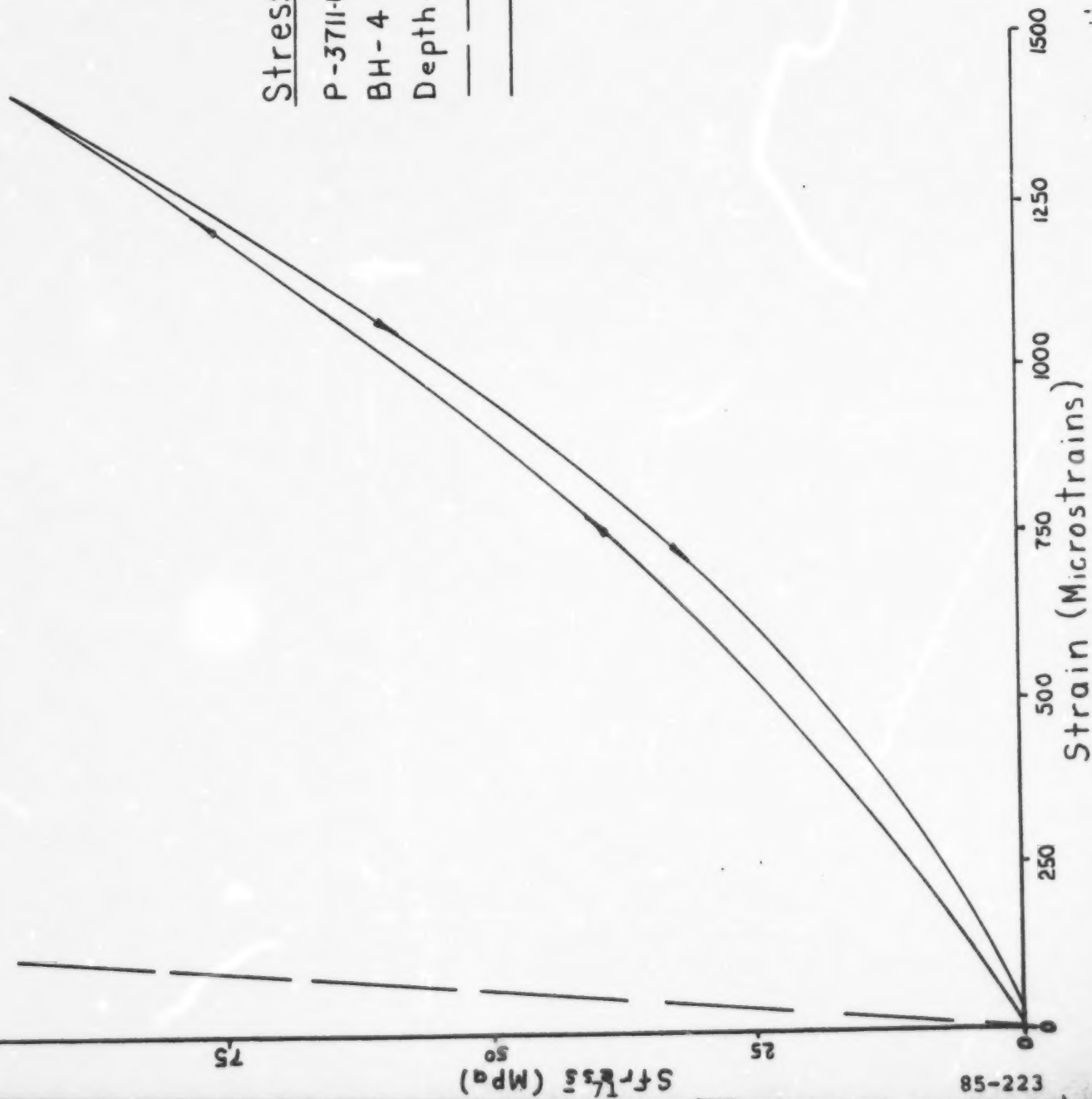
P-3711-U2

BH-4

Depth-5.63M.

— Radial

— Axial



Stress-Strain Curves

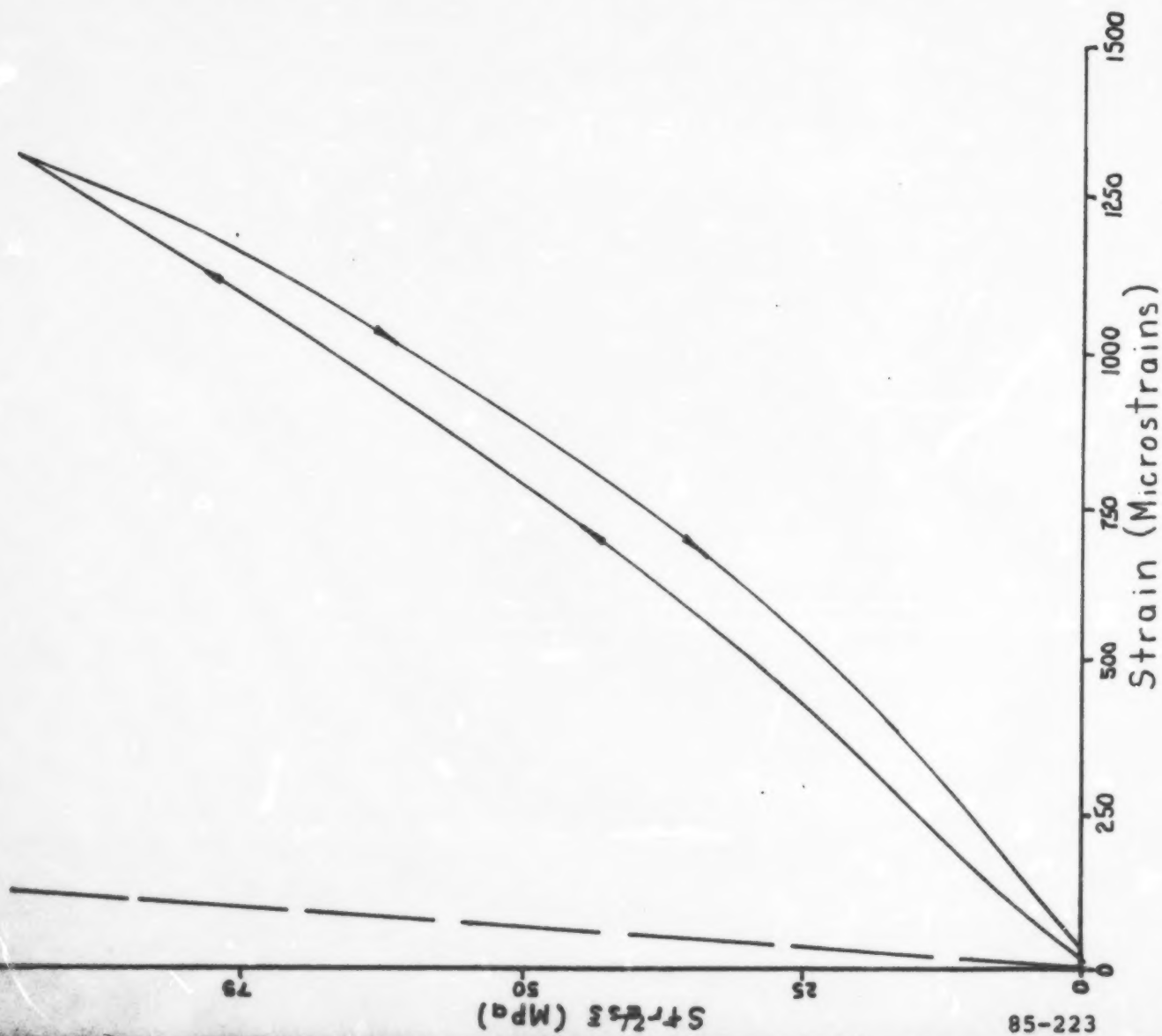
P-3711-U3

BH-4

Depth - 9.50M.

— Radial

— Axial



Stress-Strain Curves

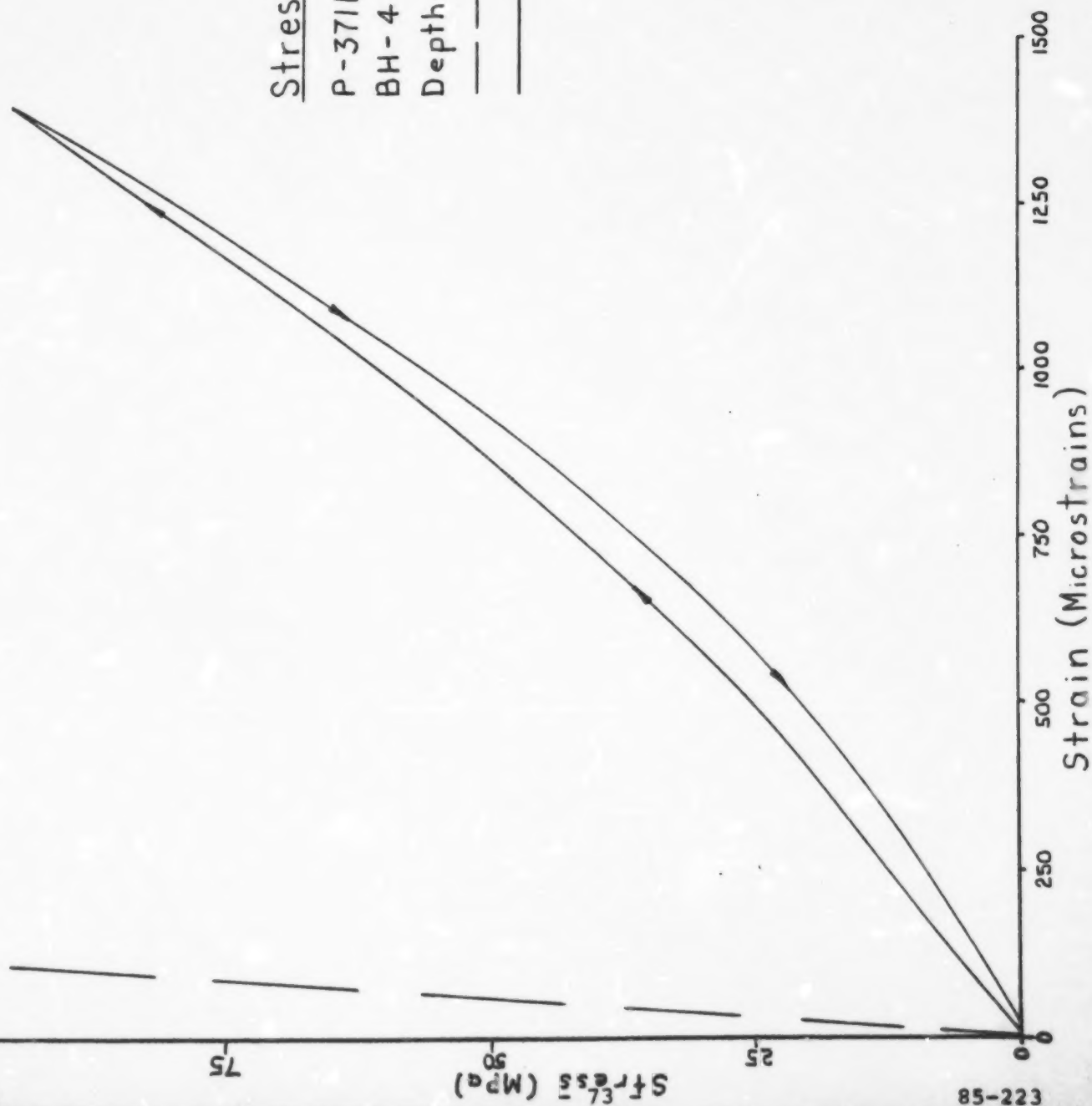
P-3711-U4

BH-4

Depth-14.48 M.

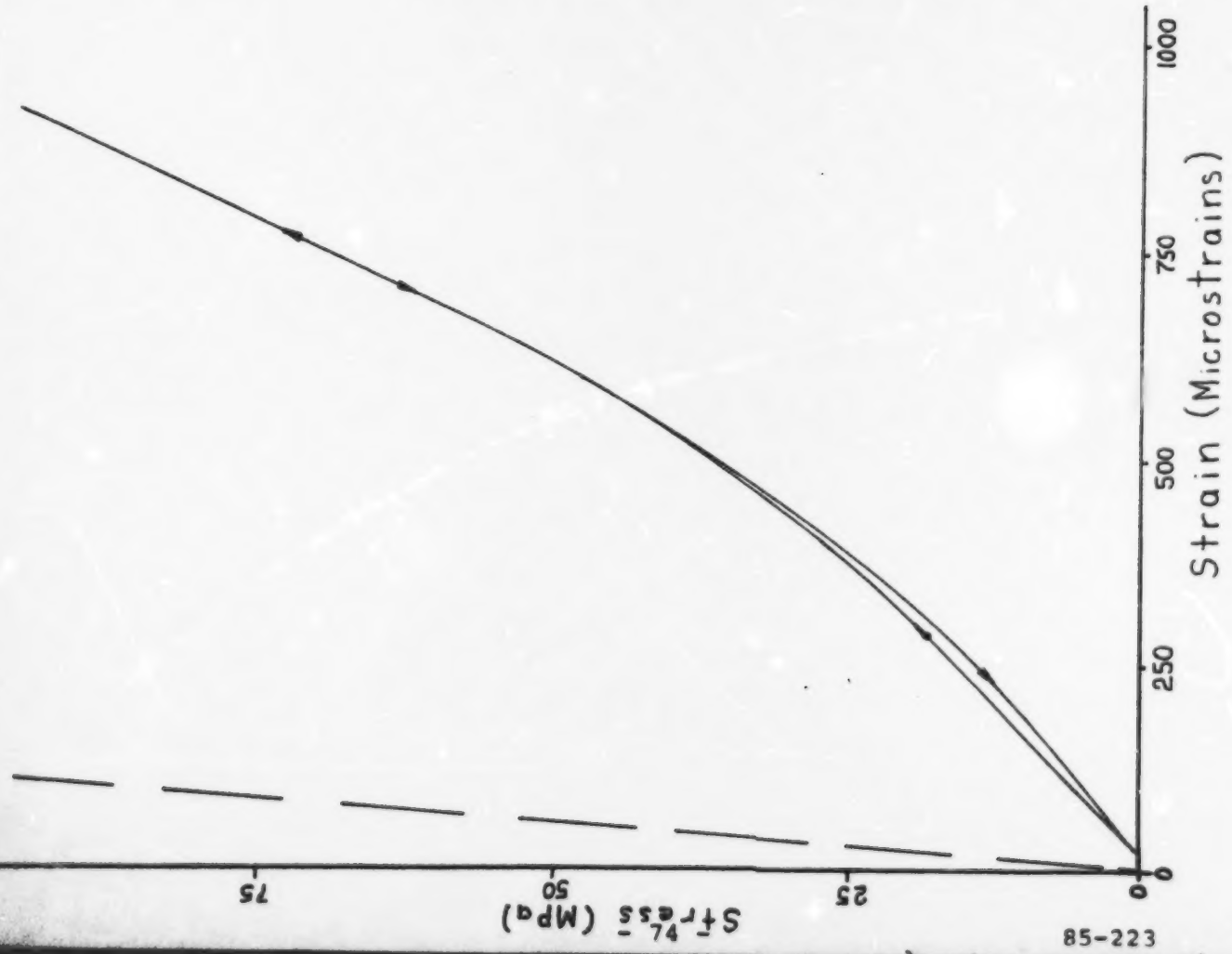
— Radial

— Axial



Stress-Strain Curves

P-3711-U5
BH-4
Depth-24.28M.
--- Radial
— Axial



Stress-Strain Curves

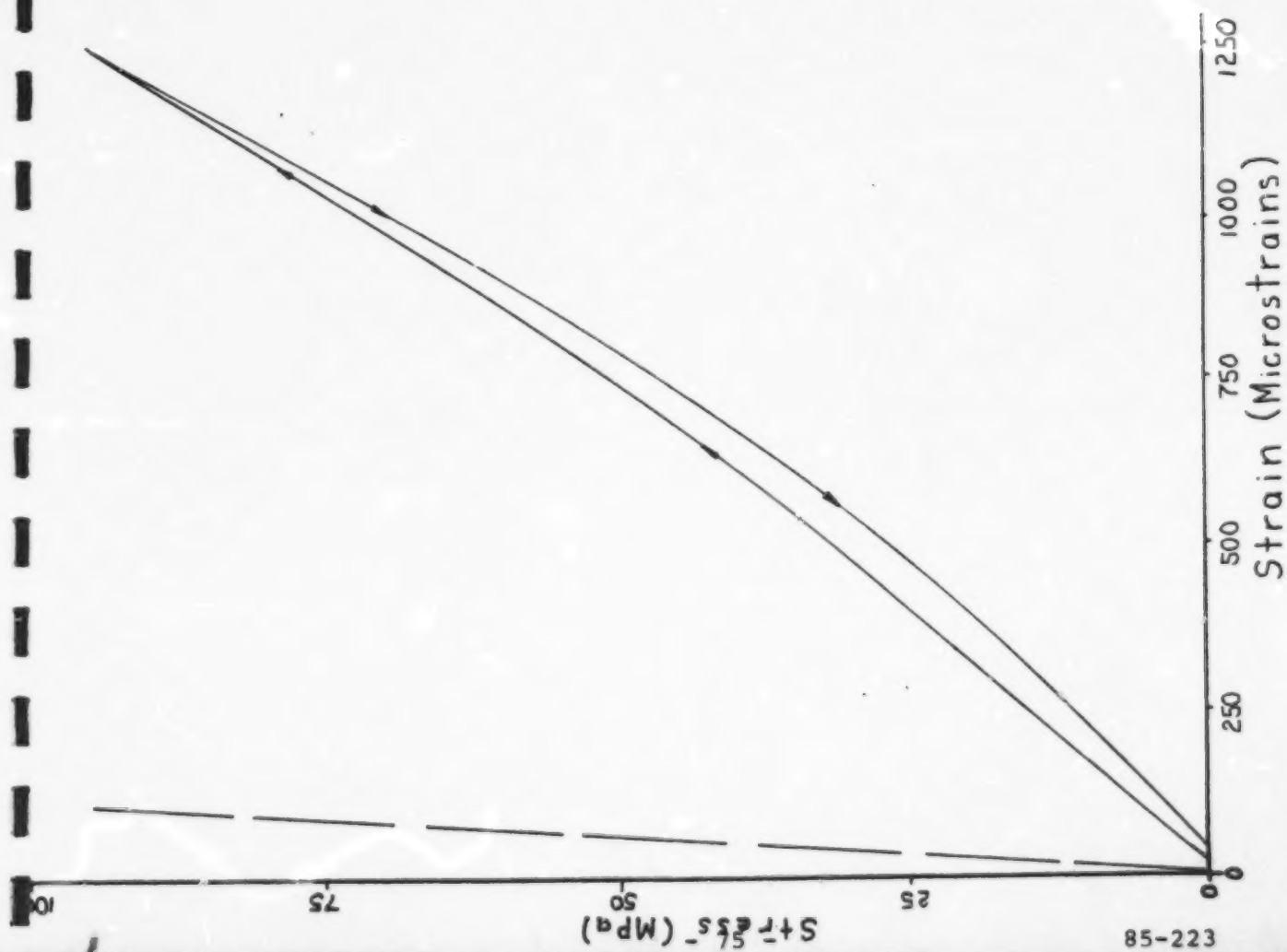
P-3711-U6

BH-4

Depth-28.48M.

— Radial

— Axial



Stress-Strain Curves

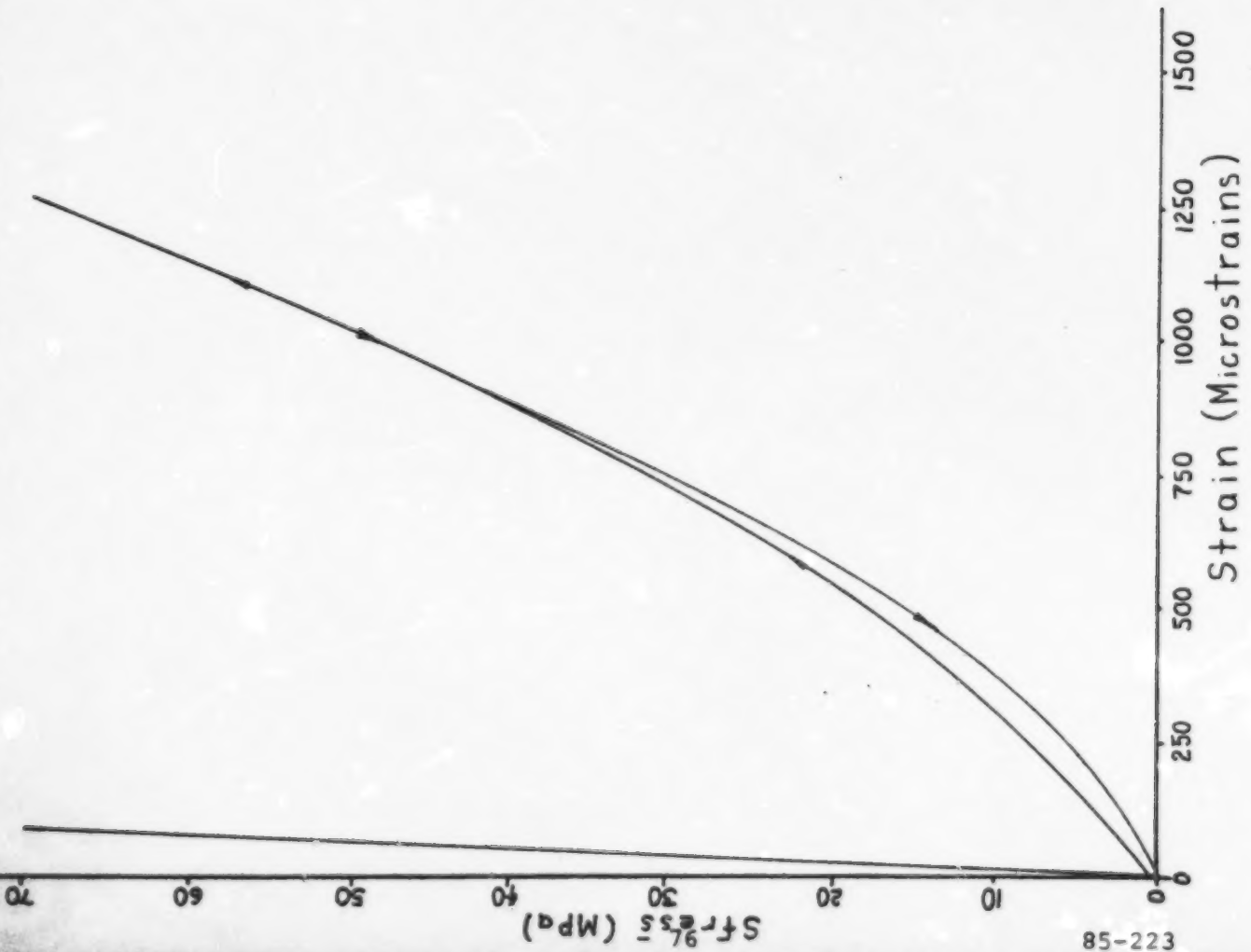
P-3712-U₁

BH-5

Depth-0.71 M.

— Radial

— Axial



Stress-Strain Curves

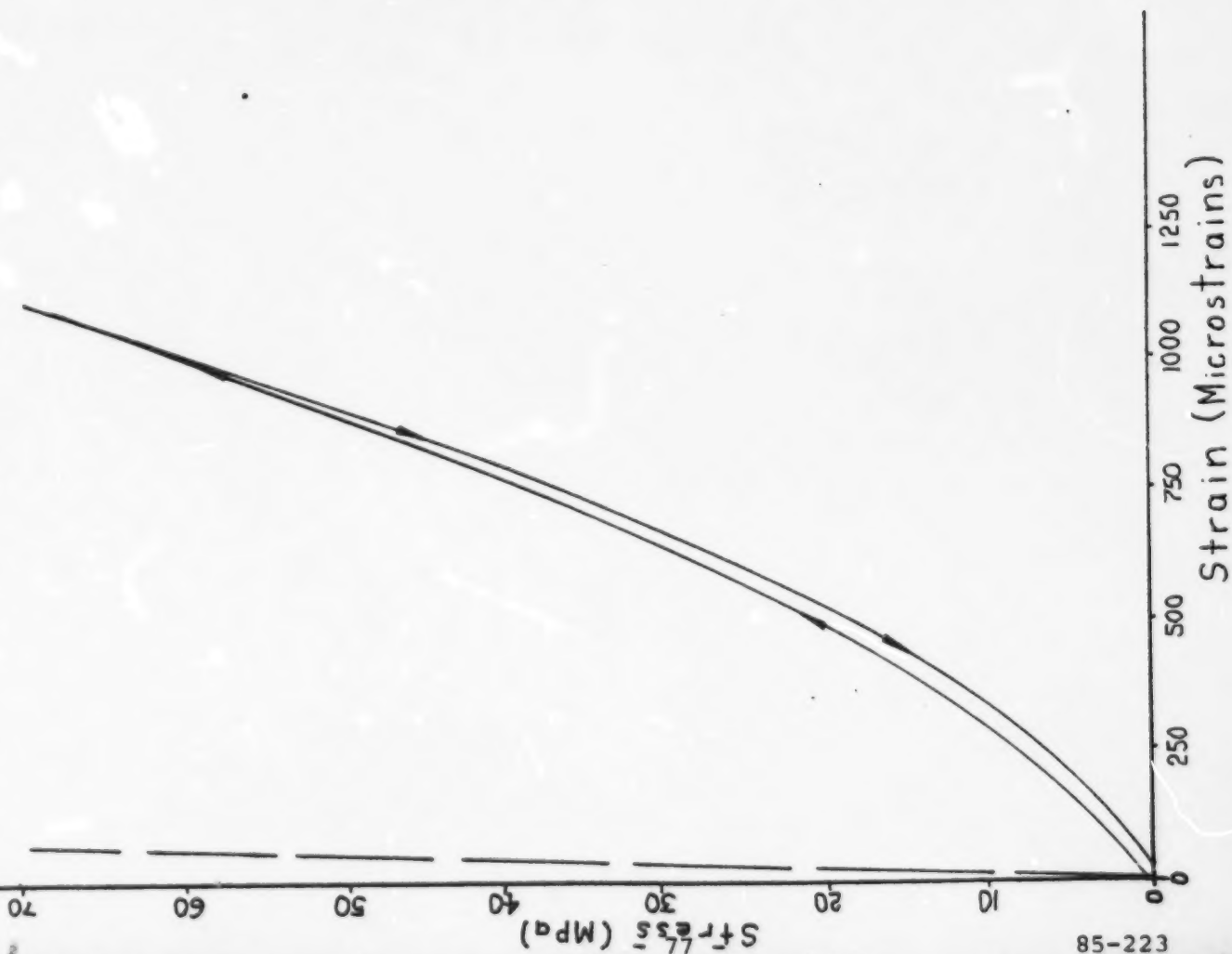
P-3712-U2

BH-5

Depth-909 M.

— Radial

— Axial



Stress-Strain Curves

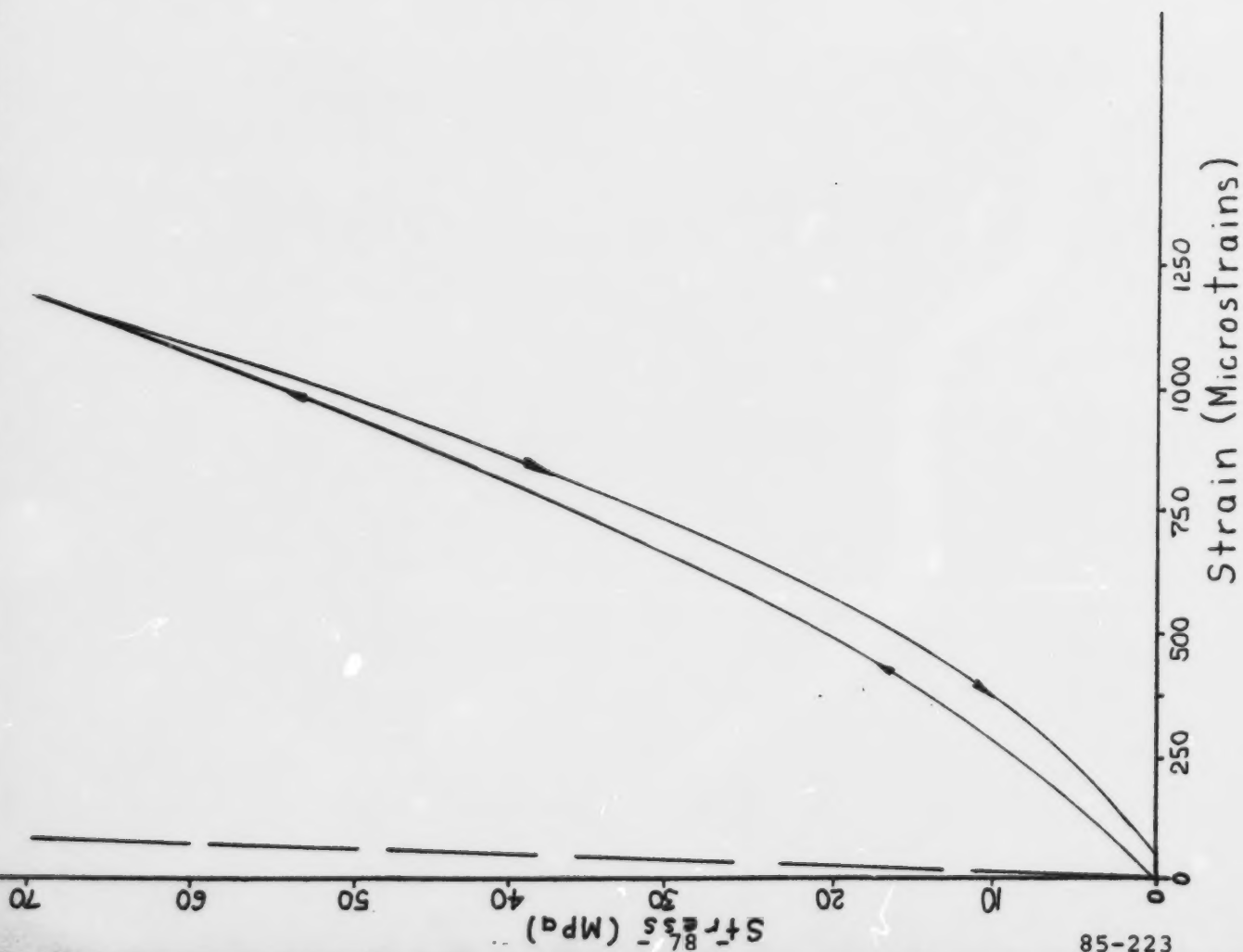
P-3712-U3

BH-5

Depth - 16.34 M.

— Radial

— Axial



Stress-Strain Curves

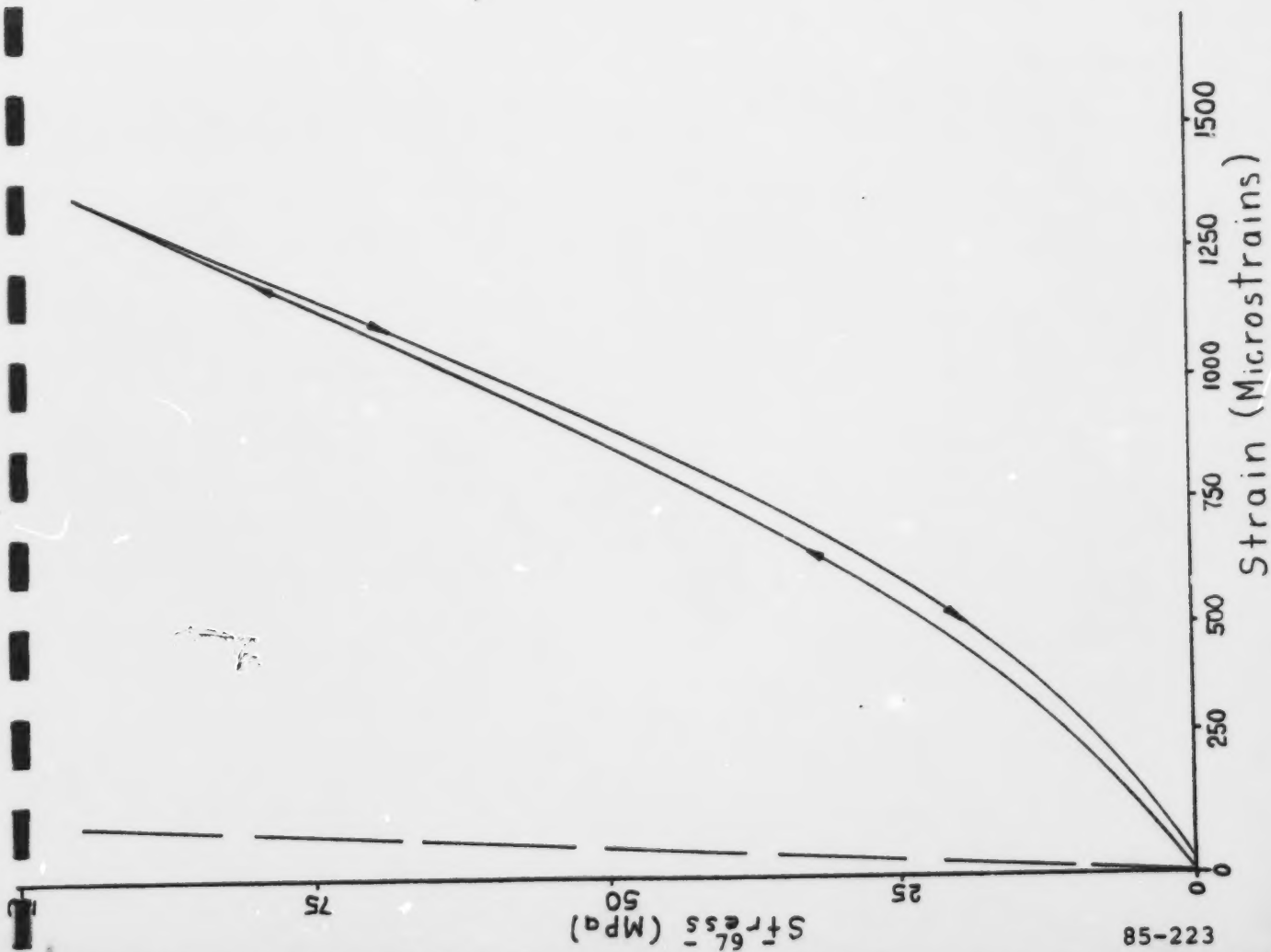
P-3712-U4

BH-5

Depth-24.71M

— Radial

— Axial



Stress-Strain Curves

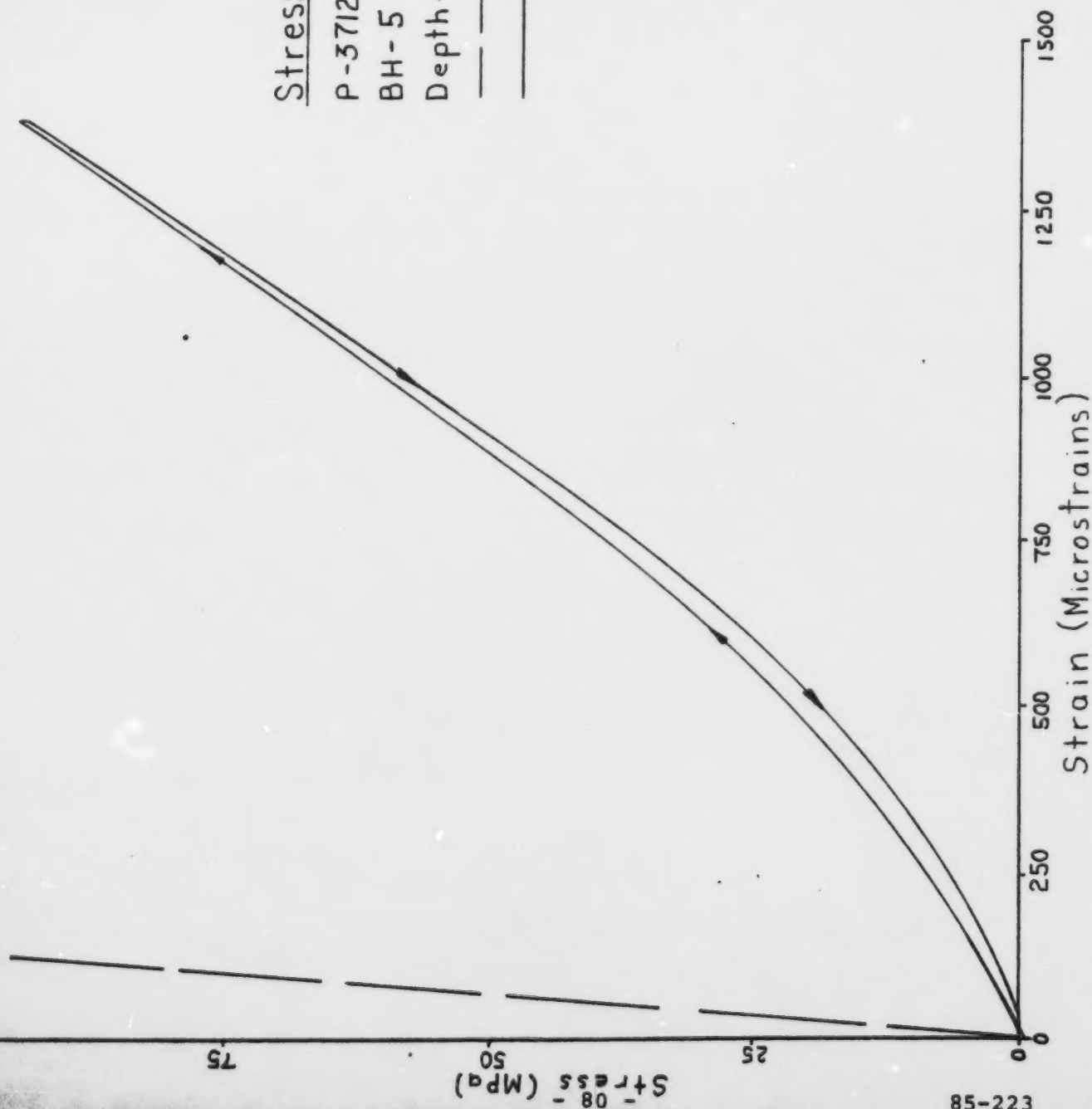
P-3712-U5

BH-5

Depth-28.96M.

— Radial

— Axial



Stress-Strain Curves

P-3713-U,

BH-6

Depth-0.04M.

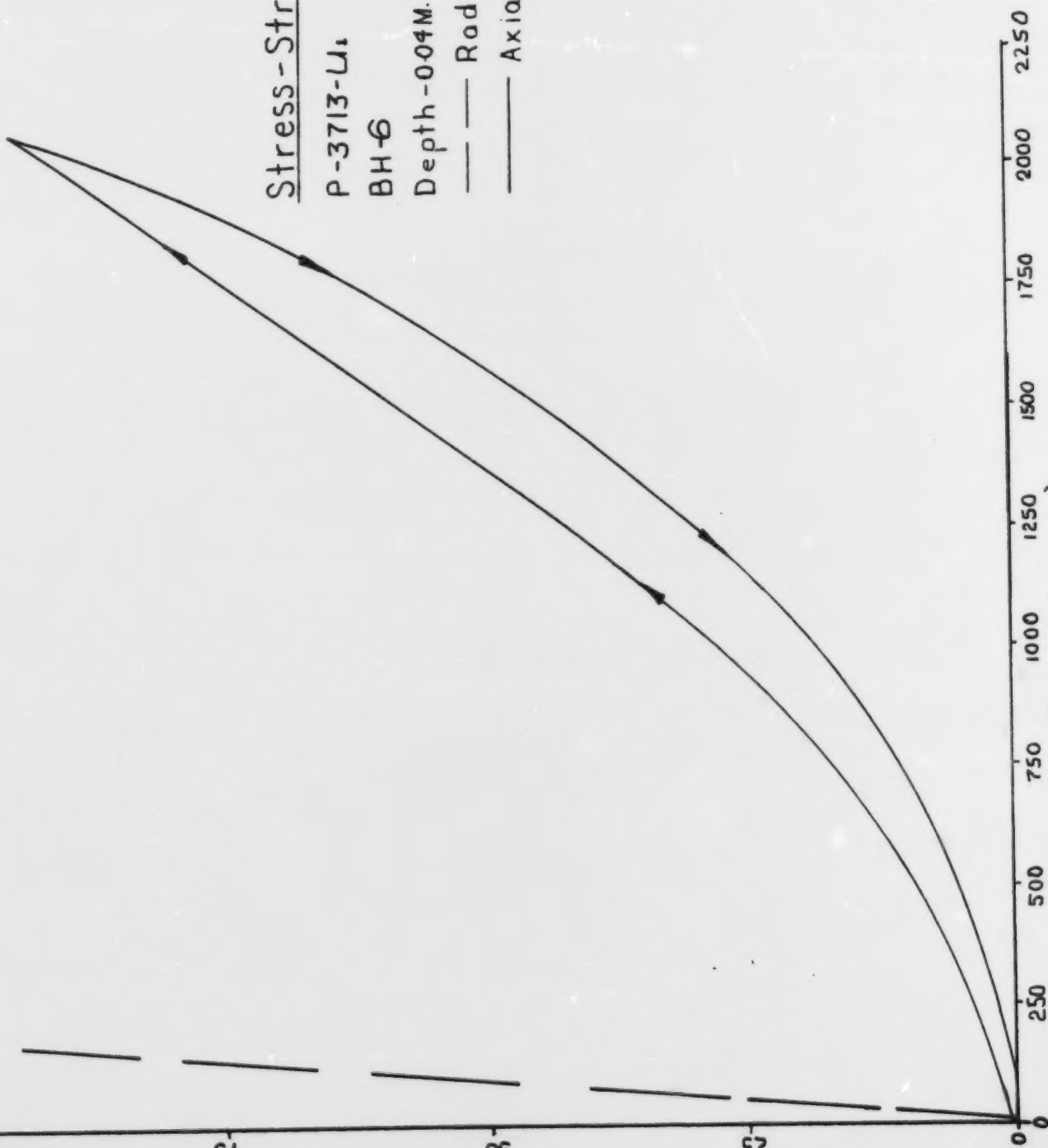
— Radial

— Axial

Stress (Mpa)

Strain (Microstrains)

85-223



Stress-Strain Curves

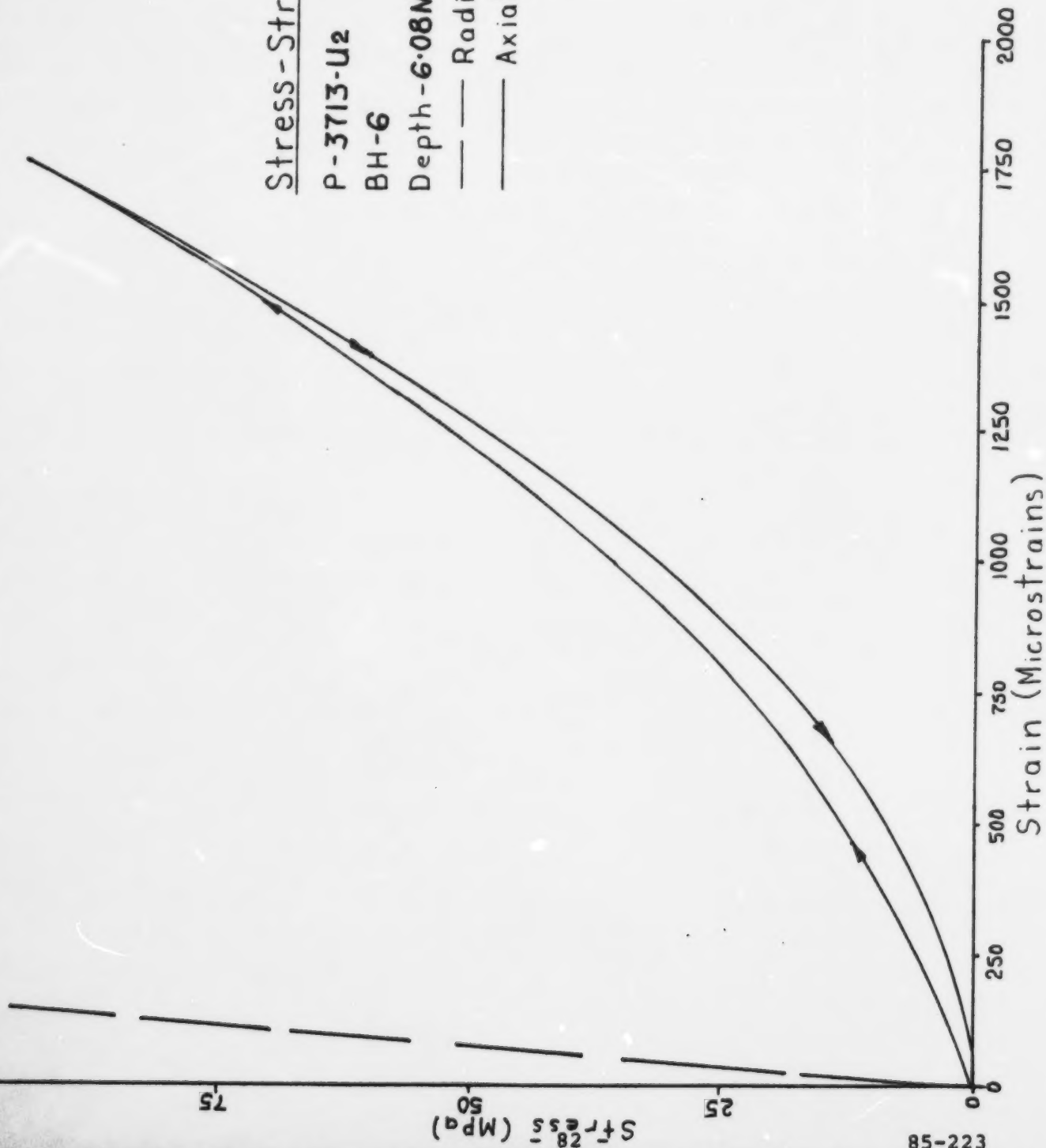
P-3713-U2

BH-6

Depth-6.08M.

— Radial

— Axial



Stress-Strain Curves

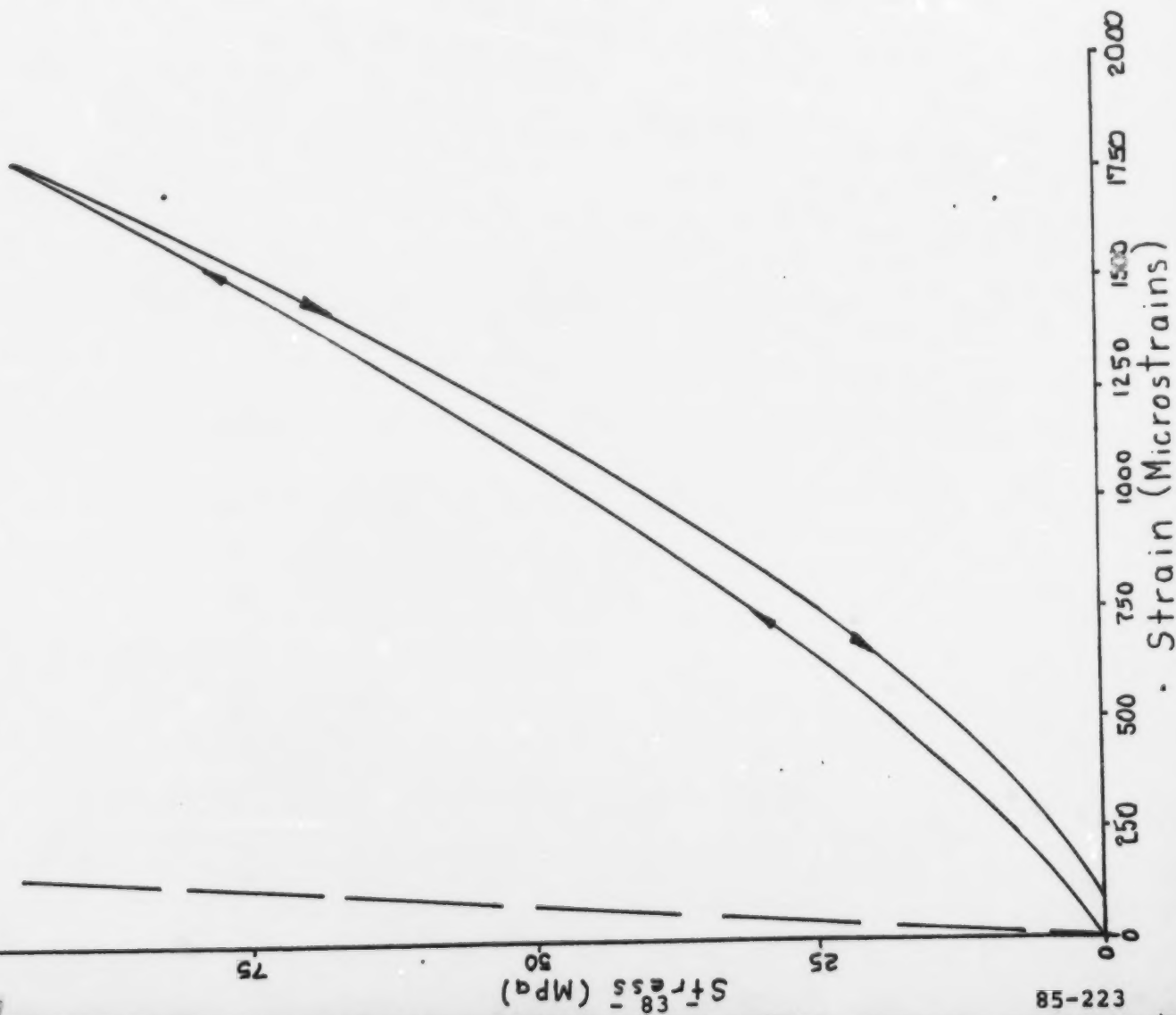
P-3713-U3

BH-6

Depth-16.72M.

— Radial

— Axial



Stress-Strain Curves

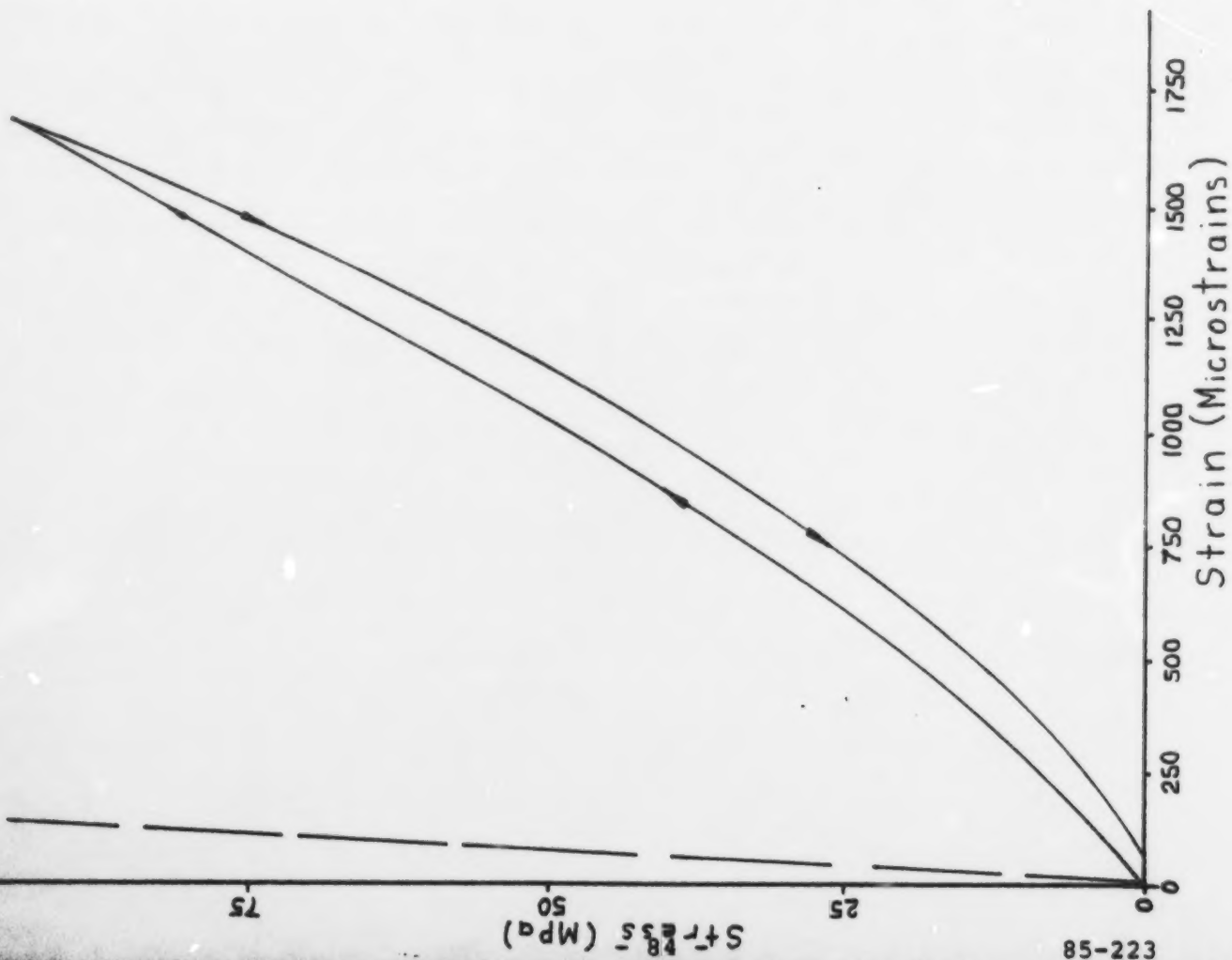
P-3711-U4

BH-6

Depth - 17.99M.

— Radial

— Axial



Stress-Strain Curves

P-3713-Us

BH-6

Depth-23.75M.

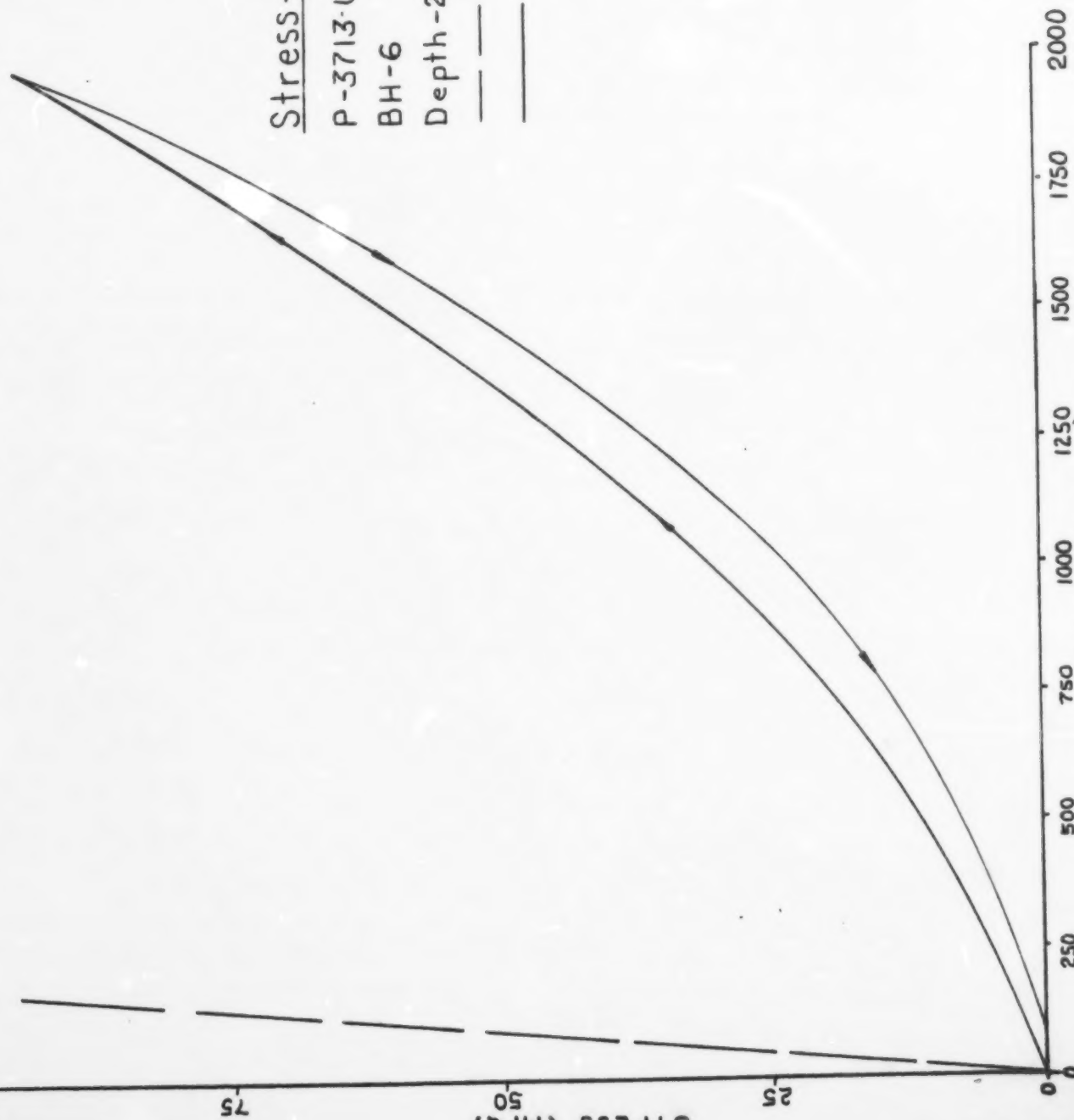
— Radial

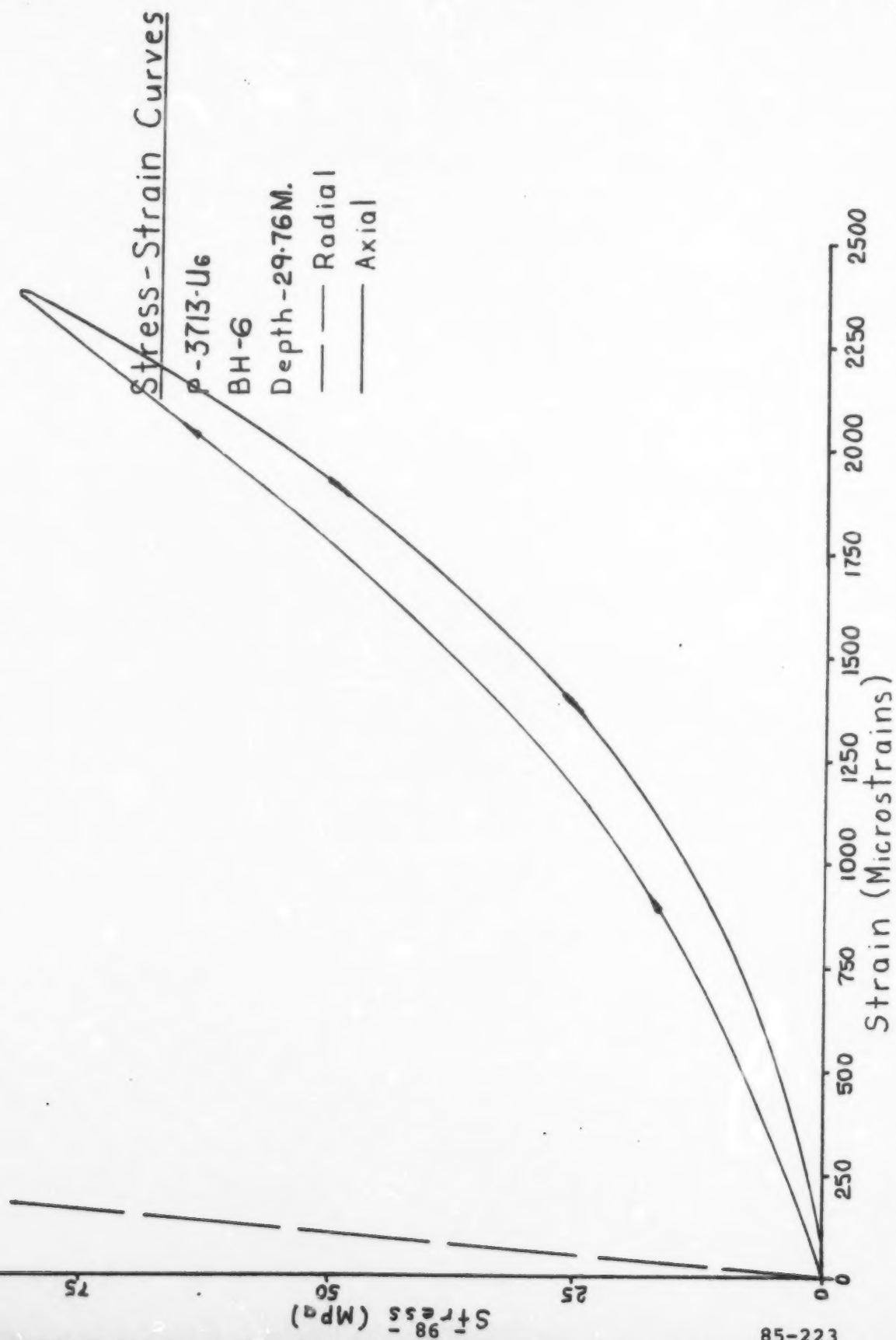
— Axial

85-223

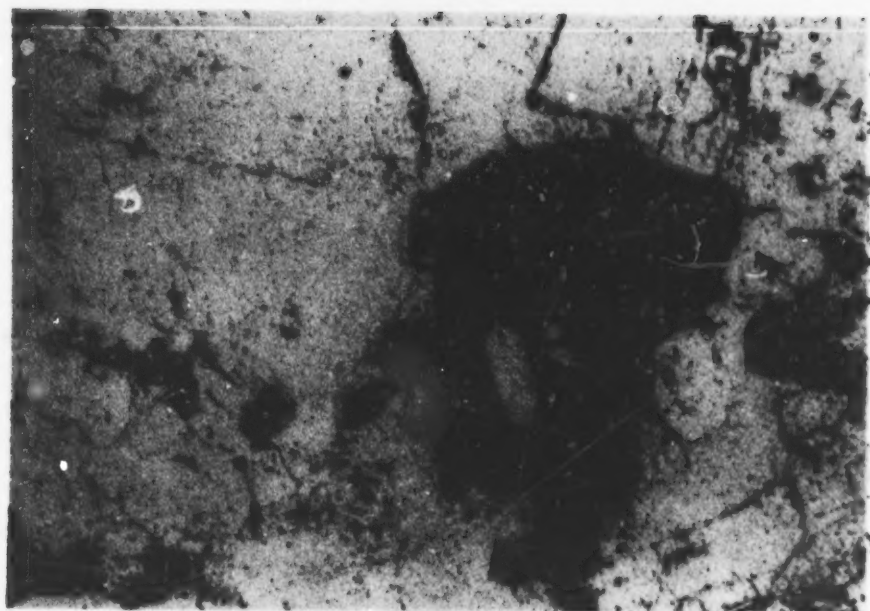
Stress (Mpa)

Strain (Microstrains)

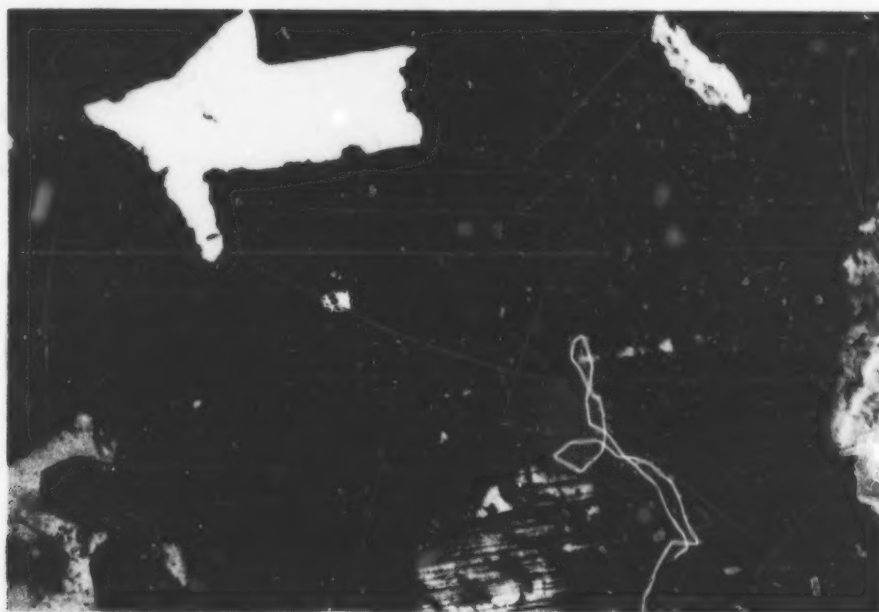




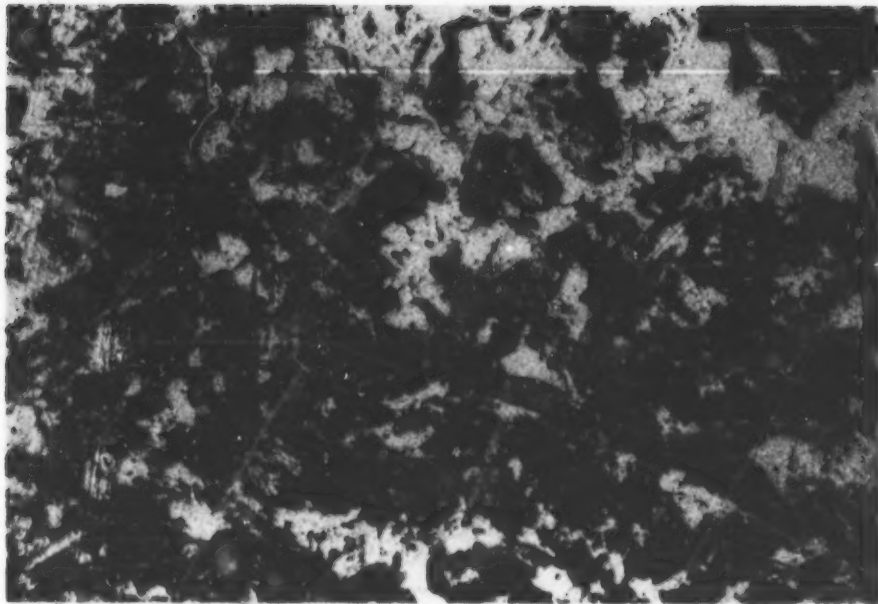
APPENDIX 2
THIN SECTION PHOTOGRAPHS



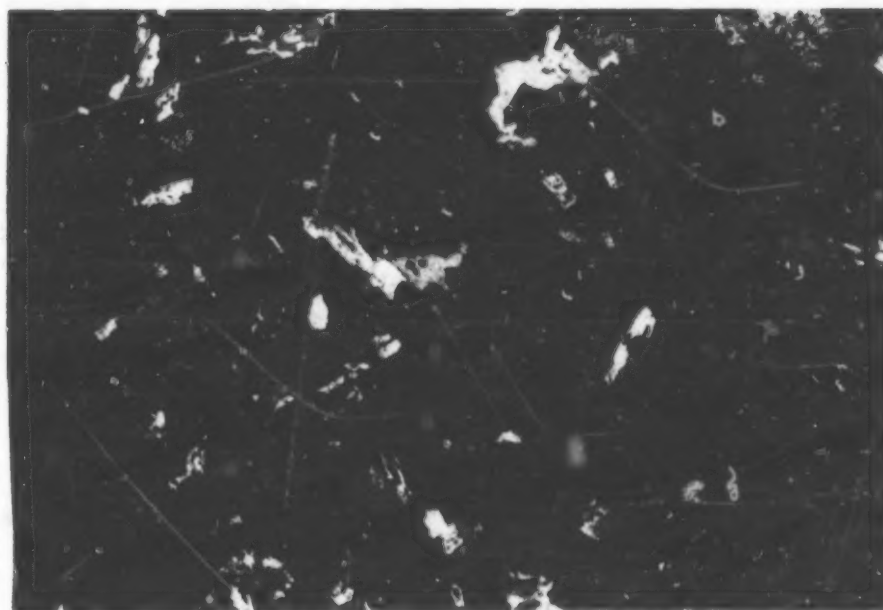
P3708 (x10 MAG) GRANODIORITE SAMPLE
BIOTITE GRAIN SURROUNDING SMALL FELDSPAR GRAIN



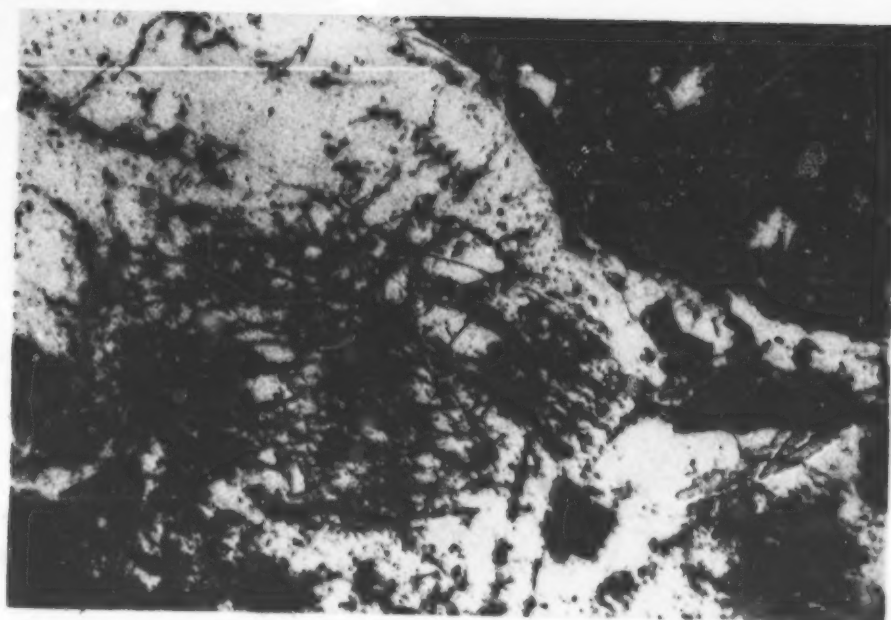
P3708 (x10 MAG) GRANODIORITE SAMPLE PERTHITE GRAIN
Note Lack of Fracture Pattern and Minor Alteration of Feldspar Grains



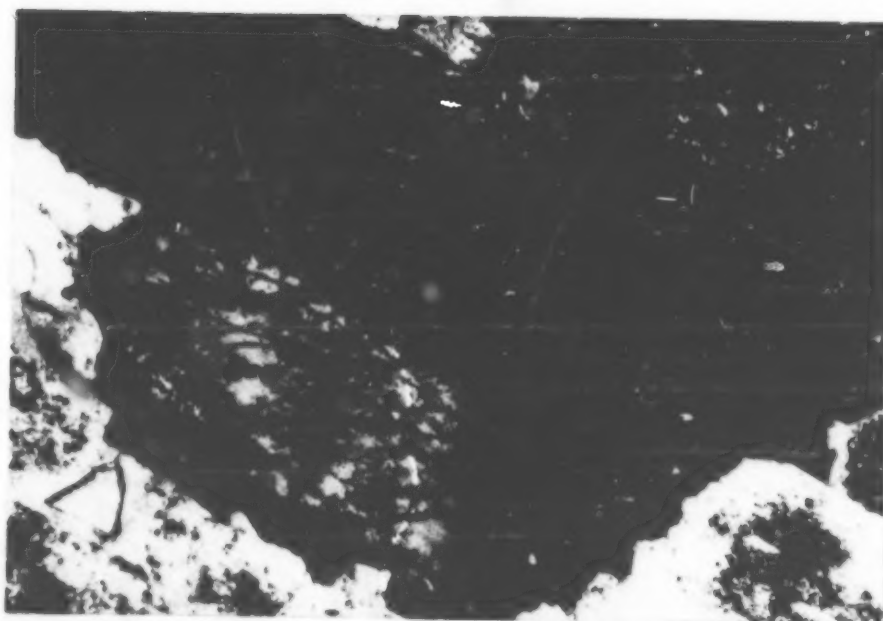
P3710 (x10 MAG) DIORITE SAMPLE



P3710 (x10 MAG) DIORITE SAMPLE
UNDER CROSSED POLARS



P3712 (x10 MAG) GRANITE SAMPLE PLANE LIGHT
Note Crack Pattern in Feldspar Grain



P3712 (x10 MAG) GRANITE SAMPLE CROSSED POLARS
Note Extent of Alteration Products Along Cracks in Feldspar

APPENDIX 3
STRESS-STRAIN CURVES
DIRECT TENSILE TESTS

MIRAMICHI 1984

Direct Tensile
Stress-Strain Curves

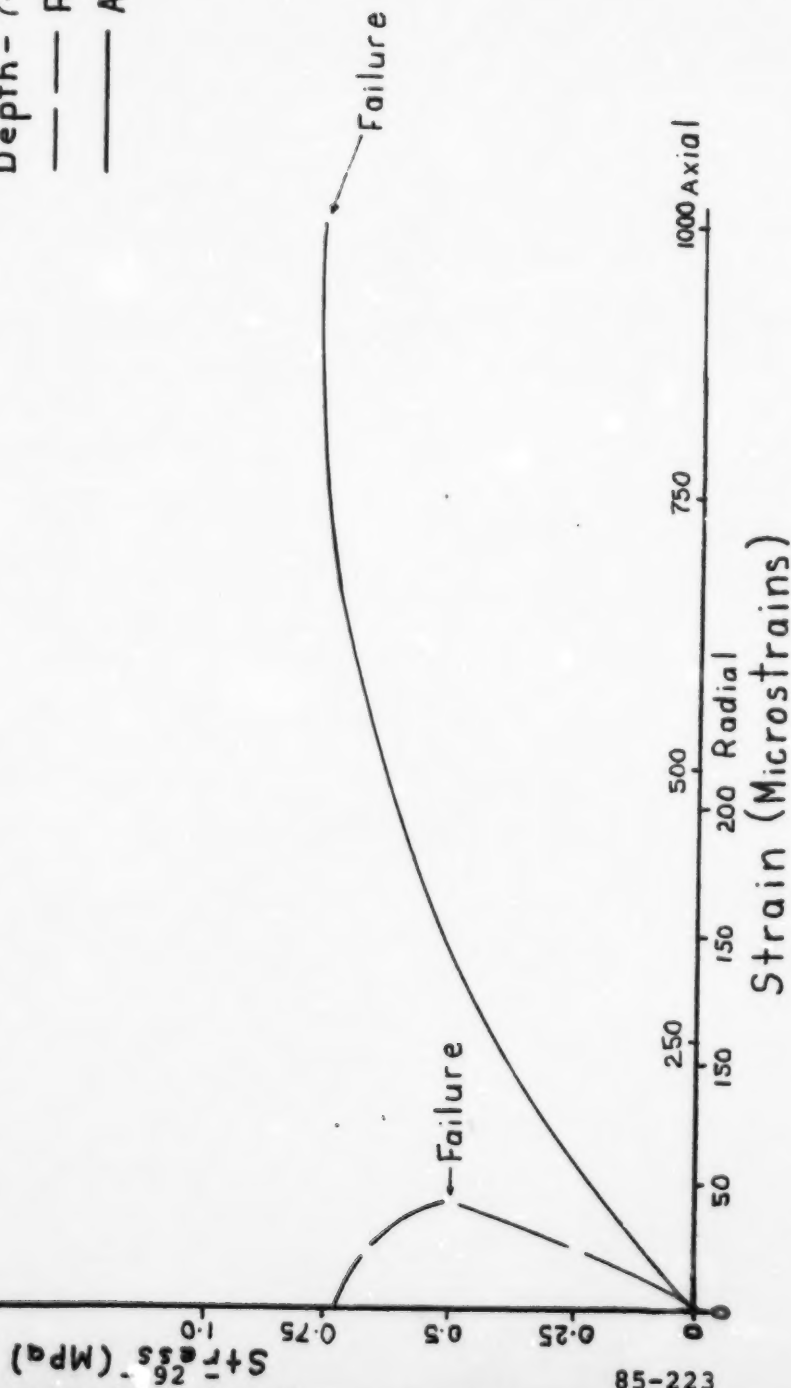
P-3708 TD-1

BH-1

Depth - 7.27 M.

— Radial

— Axial



MIRAMICHI 1984

Direct Tensile
Stress-Strain Curves

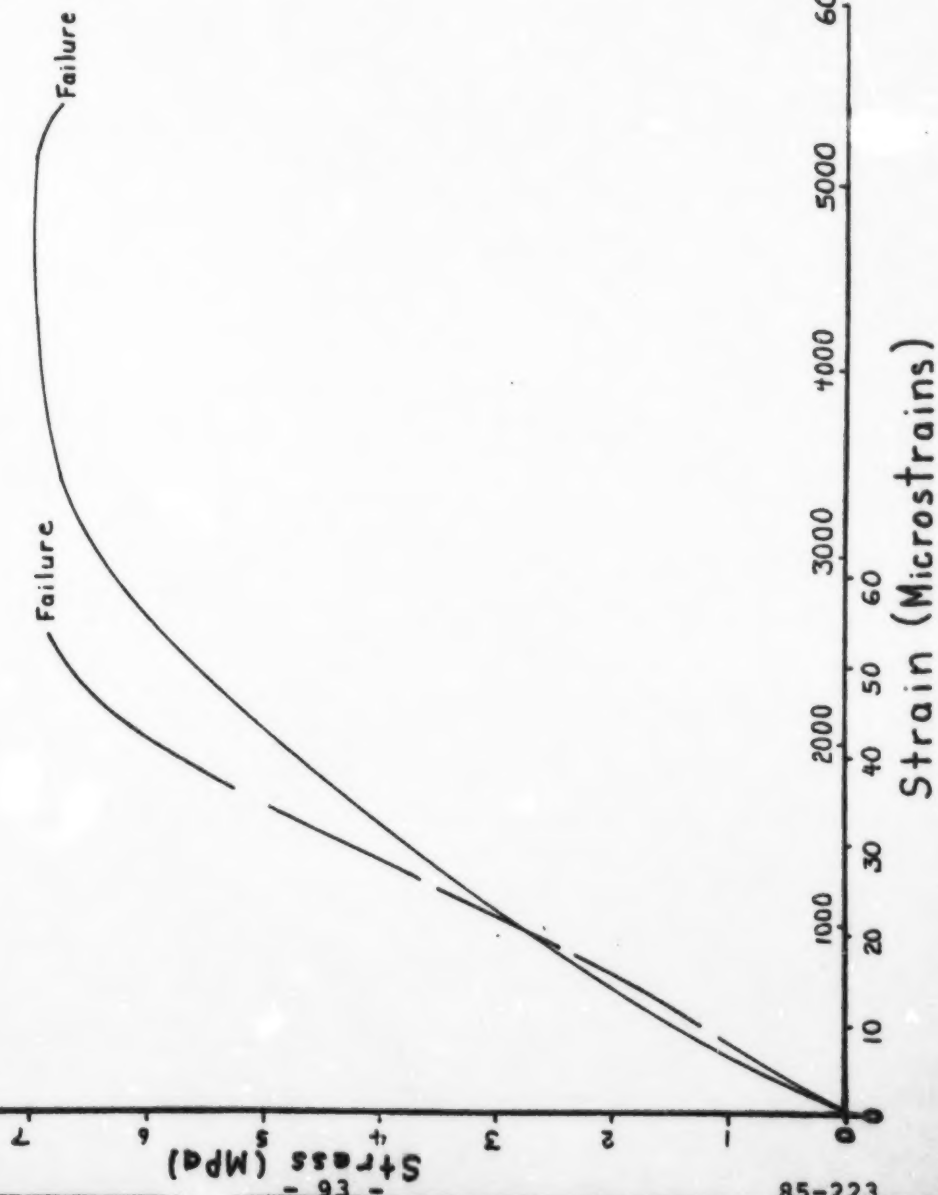
P-3709 - TD 1

BH-2

Depth - 25.58 M.

— Radial

— Axial



MIRAMICHI 1984

Direct Tensile
Stress-Strain Curves

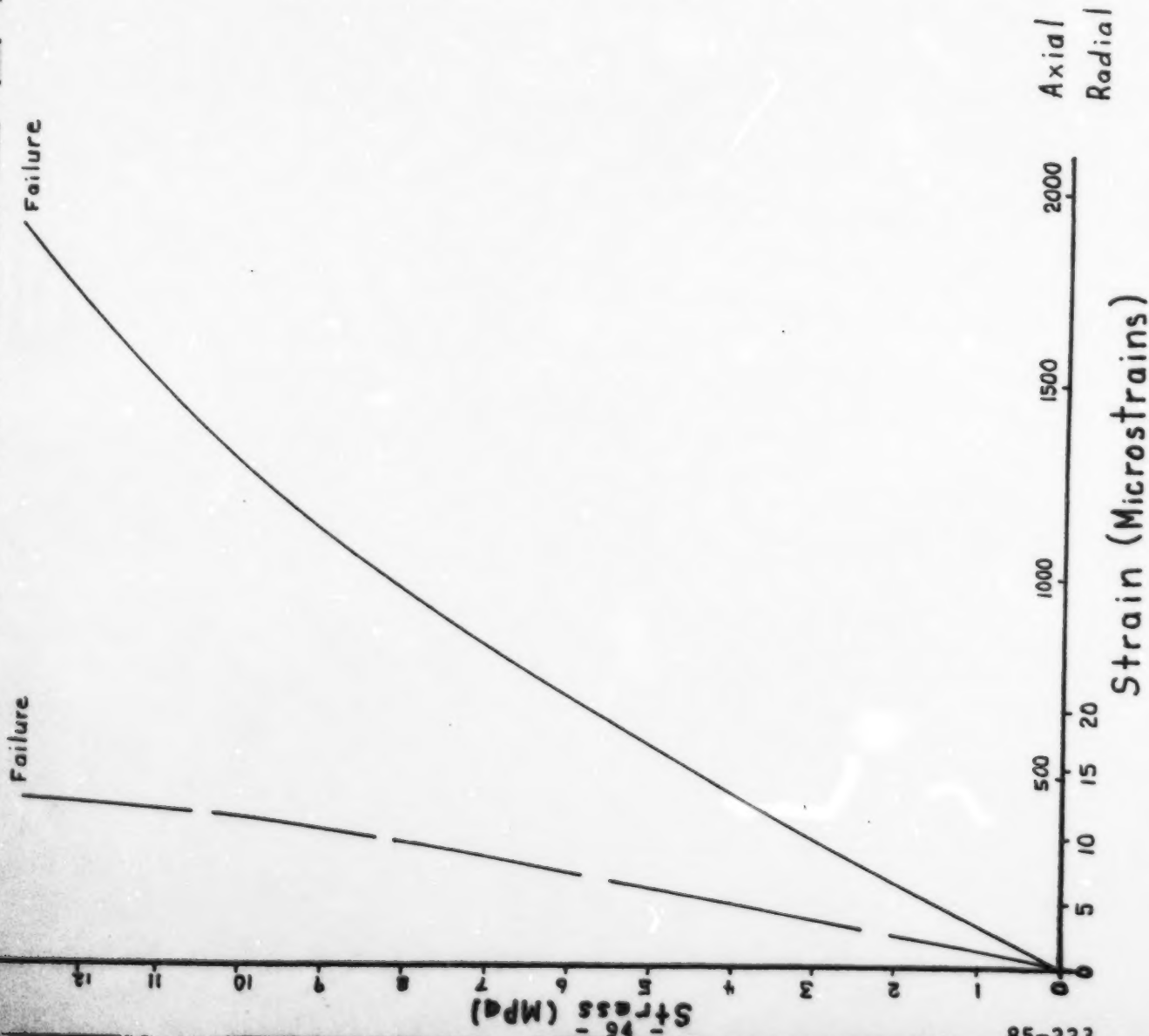
P-3710-TD1

BH-3

Depth- 17.97 M.

— Radial

— Axial



MIRAMICHI 1984

Direct Tensile
Stress-Strain Curves

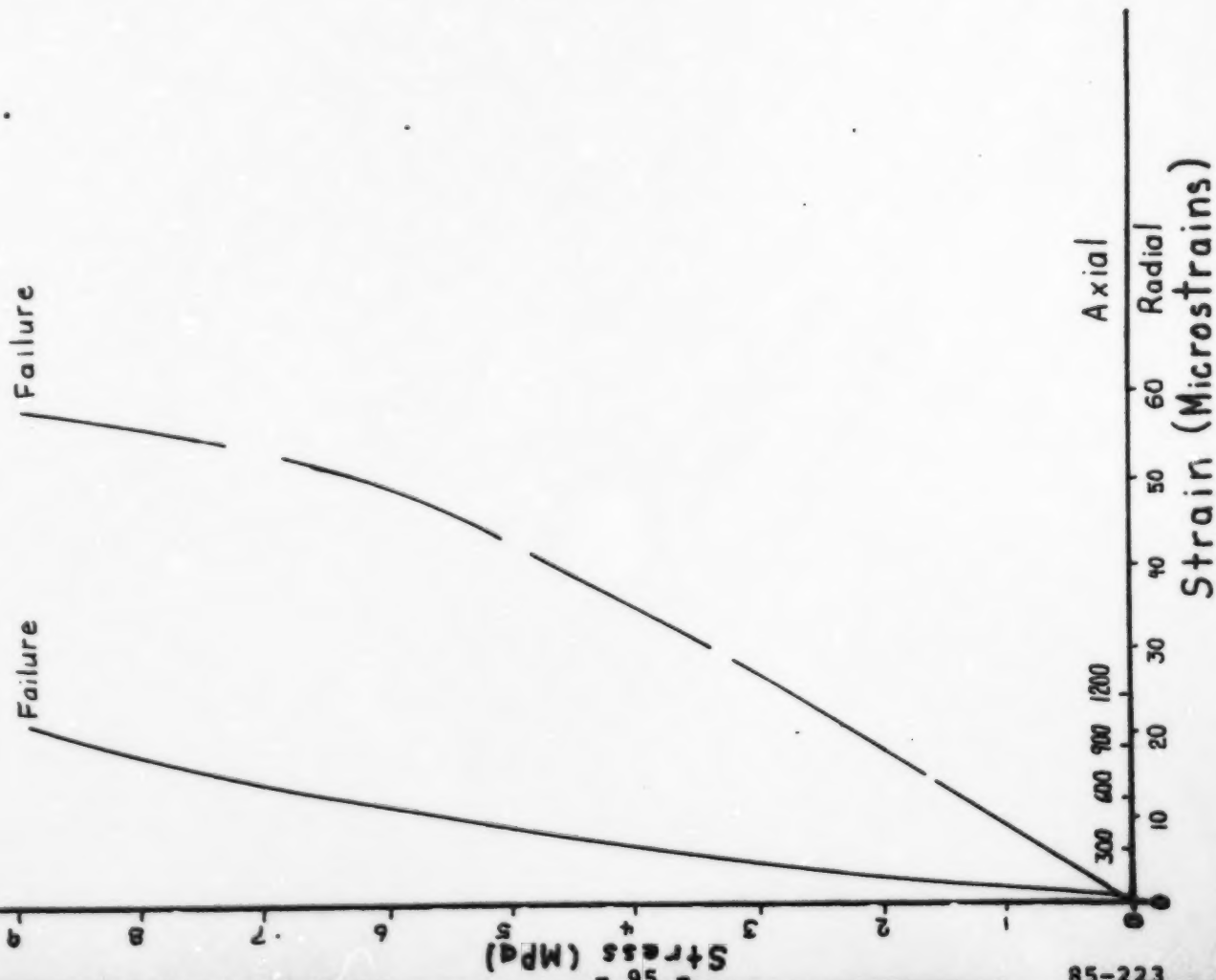
P-3711-TD1

BH-4

Depth - 9.66 M.

— Radial

— Axial



MIRAMICHI 1984

Direct Tensile
Stress-Strain Curves

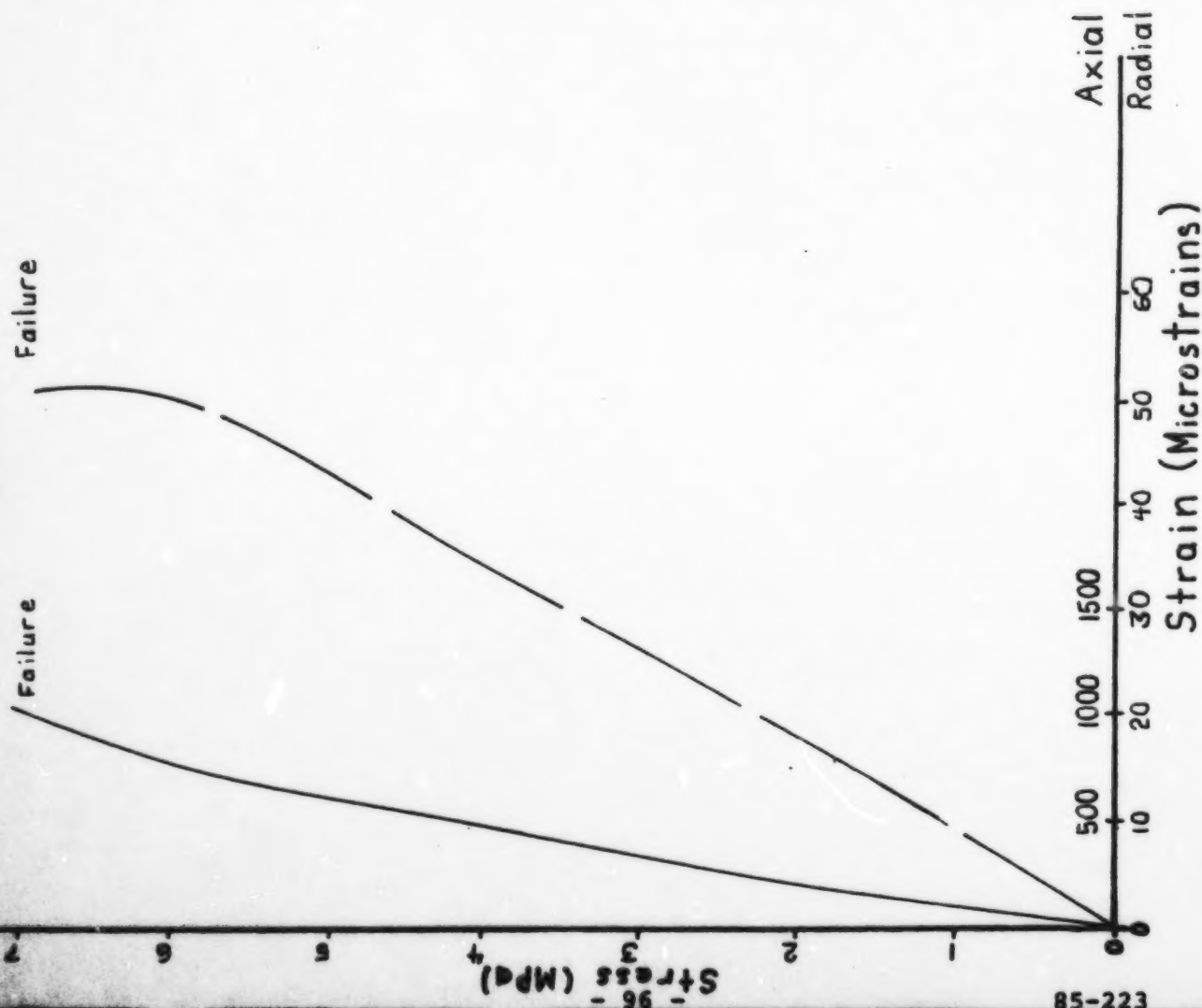
P-3711-TD 2

BH-4

Depth - 14.28 M.

— Radial

— Axial



MIRAMICHI 1984

Direct Tensile
Stress-Strain Curves

P-3713-TD1

BH-6

Depth - 18.14 M.

--- Radial

— Axial

